The Defense Science Board
1998 Summer Study Task Force

on

JOINT OPERATIONS SUPERIORITY IN THE 21ST CENTURY

Integrating Capabilities Underwriting Joint Vision 2010 and Beyond

Volume I
Final Report

October 1998

Office of the Under Secretary of Defense
for Acquisition and Technology
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DEFENSE SCIENCE BOARD

December 7, 1998

MEMORANDUM FOR UNDER SECRETARY OF DEFENSE (A&T)
CHAIRMAN JOINT CHIEFS OF STAFF

SUBJECT: Final Report of the 1998 Defense Science Board Summer Study Task on Joint Operations Superiority in the 21st Century

The final report of the 1998 Defense Science Board Summer Study Task Force on Joint Operations Superiority in the 21st Century is attached. This 1998 Defense Science Board (DSB) Summer Study continues a series of DSB studies that have examined key challenges facing America's military in the coming decade. Taken together, these studies address a wide range of threats and challenges facing the United States. Such threats include familiar conventional threats as well as less traditional threats.

This report examines capabilities and technologies to underwrite the operational concepts and goals of Joint Vision 2010 and beyond. Its central theme is that the cornerstone of a highly effective, next-generation force is early and continuous combat effectiveness with dominant force. Such a capability is necessary for combat success with the fewest casualties, at the lowest cost, and in the shortest time. This report describes a set of critical operational challenges and offers the Department recommendations associated with achieving this capability.

This Summer Study and the companion 1998 study, Logistics Transformation, have added emphasis to the close connection between effective, next-generation military operations and focused logistics. To have early and continuous combat effectiveness with dominant force, it is essential to have more agile and deployable forces and to be more responsive in theater. It also calls for a different logistics system --one with increased speed, reliability, and precision -- that minimizes stockpiles in the field relying on highly responsive lift.

I commend this report and its recommendations to your attention.

Craig I. Fields

Attachment

OFFICE OF THE SECRETARY OF DEFENSE
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DEFENSE SCIENCE
BOARD

December 7, 1998

Memorandum for the Chairman, Defense Science Board

Subject: Final Report of the 1998 Defense Science Board Summer Study Task Force on Joint Operations Superiority in the 21st Century

The final report of the 1998 Defense Science Board Summer Study Task Force on Joint Operations Superiority in the 21st Century is attached. This report consists of three volumes: Volume I presents the major findings and recommendations, Volume II provides supporting materials, and Volume III contains classified papers.

As the nation moves toward the 21st century, the United States faces a dynamic international environment that will impose new complexities in military operations. Today's adversaries are more diverse and have increasing access to asymmetric capabilities to offset US military strengths. Under the Chairman of the Joint Chiefs of Staff's *Joint Vision 2010*, the Department of Defense has embarked on a process of transforming the military to stay ahead of future security challenges. Our task force focused on new capabilities, operational concepts, and force characteristics that can be developed and integrated to underwrite Joint Vision 2010.

The task force found that the capability for early entry, and then continuous dominant combat effects across the spectrum of conflict is central to Joint Vision 2010. Key operational challenges underwriting such a capability include assured knowledge superiority, the ability to out-innovate the competition, and the ability to dominate in information operations, both offensive and defensive. We concluded that focusing on this challenging concept should help guide the Department to a superior 21st century military capability, with full spectrum dominance – the central goal of Joint Vision 2010.

Our primary recommendation is that Early and Continuous Combat Effectiveness be a major organizing construct for the Department's pursuit of Joint Vision 2010. It addresses a central and critical challenge facing the US military and will provide needed focus for the transformation to a 21st century force. The report identifies a set of specific recommendations that contribute building blocks for this capability. Since implementing the needed mix of initiatives will be a complex undertaking, exacerbated

by the many competing demands for resources, the Secretary must lead this implementation process, with the active involvement of the Chairman, Joint Chiefs of Staff and the Under Secretary of Defense for Acquisition and Technology.

We thank the Task Force members and the talented group of government advisors for their hard work and valuable insights. Their dedication reflects their belief in the importance of this challenge to the Department.

Donald Latham, Co-Chair

Larry Welch, Co-Chair

DEFENSE SCIENCE BOARD
1998 SUMMER STUDY

Joint Operations Superiority in the 21st Century

Integrating Capabilities Underwriting Joint Vision 2010 and Beyond

Full Spectrum Dominance will be the key characteristic we seek for our Armed Forces in the 21st century. ... we will move toward a common goal: a joint force – persuasive in peace, decisive in war, preeminent in any form of conflict.

JOINT VISION 2010

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PREFACE

The 1998 Defense Science Board (DSB) summer studies – *Joint Operations Superiority in the 21st Century* and *Logistics Transformation* – continue from a series of studies that have examined key challenges facing America's military in the coming decade. In the 1995 summer study, *Investments for 21st Century Military Superiority*, a task force examined Department of Defense (DoD) missions to identify where new research and development investments would be appropriate to ensure military superiority.

The following year, in the report *Tactics and Technologies for 21st Century Military Superiority*, the DSB investigated ways to achieve substantial increases in the effectiveness of rapidly deployable forces and took a more comprehensive look at the missions identified in the 1995 report. A second report in 1996, *Achieving an Innovative Support Structure for 21st Century Military Superiority*, examined the Department's vast support system and offered recommendations for a "revolution in business affairs," drawing from successful business practices in the commercial sector. The 1997 summer study task force looked at a growing dimension of the threat – the transnational threat – in its report *DoD Responses to Transnational Threats*.

The Defense Science Board has also examined many additional topics linked to specific recommendations of the previous summer studies. These studies are highly relevant and support the 1998 summer study efforts. Topics include Coalition Warfare, Nuclear Deterrence, Underground Facilities, Information Warfare Defense, Ballistic and Cruise Missile Defense, and Urban Warfare.

Taken together, these studies addressed a wide range of threats facing the United States. Such threats include familiar conventional threats – high performance platforms, centralized command and control, precision, and even nuclear weapons. The threat also extends to the transnational threat: adversaries that may have no homeland; weapons that may include biological, chemical, and information warfare; command and control systems that may include the internet and other commercial communication networks; and means of force projection that may include commercial carriers common throughout the business community.

This spectrum of threats is individually and collectively difficult and challenging. It is possible for even an adversary with a relatively small budget to become a significant regional threat. Large quantities of inexpensive missiles, even last-generation weapons, require thoughtful counters. Underground facilities, land and sea mines, and unconventional threats like information warfare are in the hands of many adversaries today and are likely to be available to even more in the future. Coupled with America's high concern for human life and the lack of concern for human life held by many adversaries, the 21st century threat is diverse and formidable.

DSB studies have also addressed the need and the means to pay for many of the changes needed to maintain military superiority into the 21st Century – a "revolution in business affairs." By improving the effectiveness and efficiency of DoD's business operations, significant resources can be made available to transform the Department's military capabilities. The Department of Defense has taken these lessons to heart as many changes in both military and business affairs have been underway in recent years. But progress is slow.

To this legacy of studies, the 1998 summer studies have added emphasis to the close connection between effective, next-generation military operations and focused logistics. To have early and continuous combat effectiveness with dominant force, it is essential to have more agile and deployable forces and to be more responsive in theater. It also calls for a different logistics system – one with increased speed, reliability, and precision – that minimizes stockpiles in the field, relying on highly responsive lift. Moreover, both early entry with dominant force and a transformed logistics system depend on a common, modernized, and secure information infrastructure.

This report, *Joint Operations Superiority in the 21st Century,* examines capabilities and technologies to underwrite the operational concepts and goals of Joint Vision 2010 and beyond. The central theme is that the cornerstone of a highly effective, next-generation force is *early and continuous combat effectiveness with dominant force*. Such a capability is necessary for combat success with the fewest casualties, at the lowest cost, and in the shortest time. This report describes a set of critical operational challenges and offers the Department recommendations associated with achieving this capability.

EXECUTIVE SUMMARY

As the nation moves toward the 21st century, the United States faces a dynamic international environment that will impose new complexities in military operations. Today's adversaries are more diverse and have increasing access to asymmetric capabilities to offset US military capabilities. The Department of Defense is embarking on a process of transforming the military to stay ahead of future security challenges. Although the United States currently has clear military superiority, maintaining these advantages will require a balance between maintaining relevant legacy forces, facilities, and systems and developing new capabilities.

The Joint Chiefs of Staff have provided a vision for this transformation, *Joint Vision 2010* – a conceptual template for what America's Armed Forces will need to be to provide new levels of joint warfighting effectiveness in the future. At the request of the Chairman, Joint Chiefs of Staff and the Under Secretary of Defense for Acquisition and Technology, the Defense Science Board 1998 Summer Study task force addressed integrating capabilities underwriting Joint Vision 2010 and beyond. More specifically, as stated in the terms of reference, the task force focused on "how new capabilities, operational concepts, and different force characteristics can be developed and integrated to underwrite Joint Vision 2010."

FUTURE ENVIRONMENTS

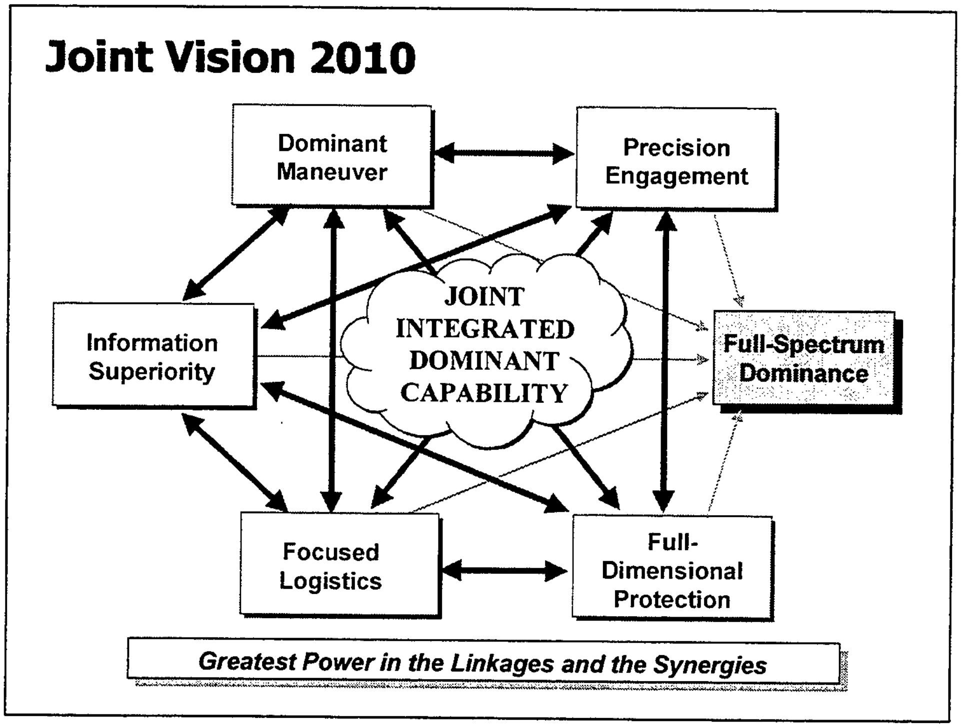
While dealing with uncertainty about future circumstances is in itself a major undertaking, trends in the international security environment and the quickening spread of technology offer insights to specific challenges the United States will face. Particularly worrisome are countries and groups hostile to the United States that are exploiting asymmetries that, if left unanswered, could greatly narrow US advantages. These asymmetries include:

- Penetrating and attacking communications networks on which America's society and military forces depend heavily;
- Acquiring mass casualty weapons, longer-range ballistic and cruise missiles, and access to commercial space systems;
- Shielding key assets underground, among non-combatants and at places of international cultural importance, to protect them from aerial surveillance and attack; and
- Creating links to transnational groups and criminal organizations whose activities blur distinctions between law enforcement and military responsibilities.

Biological and information warfare in particular pose direct threats to America's homeland as adversary nations, radical movements, and criminal groups become more ambitious in their aims and more aggressive in their pursuit. Against that backdrop, decision times will be compacted and there will be a premium on terminating conflicts – both large and small – quickly and decisively to minimize their consequences and chances of recurrence.

This appraisal of the future security environment highlights the need for America's armed forces to organize, train, equip, and operate in fundamentally new ways, a view implicit in Joint Vision 2010. Joint Vision 2010 goes beyond providing a joint perspective on future military capabilities. It posits objectives for future US military capabilities – the notion of full spectrum dominance in all circumstances and environments – that are much more ambitious than America's cold war objectives. Thus, Joint Vision 2010 establishes full spectrum dominance as the standard for transformation. Credible forward deployed presence coupled with the ability to deploy quickly from peacetime bases and stations to operations worldwide are called for in answer to the challenges of a variety of potential contingency environments.

Joint Vision 2010's greatest power lies in the linkages and synergies among information superiority, dominant maneuver, precision engagement, focused logistics and full-dimensional protection. It is essential that the focus go beyond the individual boxes on the chart below. Organizations and processes need to be constituted to exploit these linkages and synergies. Fundamental to transformation is experimentation with innovative concepts and procedures that take advantage of these synergies and technology's expanding potential.



While others are exploiting asymmetries, US military forces have powerful asymmetrical capabilities of their own that should be protected and enhanced. They include quality people whose talents and aptitudes are sharpened by unmatched training; a force with global knowledge, global presence, and global reach; information systems whose quality and rapid evolution lead

the world; and an unparalleled ability to apply joint force worldwide with precision fires, operational stealth, and dynamic maneuver.

Unstated in Joint Vision 2010, but essential, is the need for operations to be conducted with the consent, cooperation, and support of coalition partners and hosts. Operations other than war and smaller scale contingencies create a similar need for cooperation with federal and state authorities and private relief organizations. Therefore, it is important that advances in US military capabilities accommodate effective operation with other countries' forces, other agencies of the US government, and non-government organizations.

INTEGRATING CONCEPTS AND BROAD NEEDS

The Services are reaching similar conclusions about the future, recognizing the need to move from peacetime bases and stations directly into action with immediately effective operations and the need to bring decisive effects to bear quickly rather than depending on protracted and vulnerable force and logistical buildups. *Army After Next*, the *Air Expeditionary Force*, and *Operational Maneuver from the Sea* all reflect a changing security environment and emphasize the need for fast, flexible, and decisive forces armed with the advantages technology can provide. Still, despite considerable commonality among those concepts, there is a need for focus beyond Joint Vision 2010 to unify them and generate the synergy they could offer.

Integrating the Services' concepts under a unifying joint concept can provide a foundation for the development of consensus upon which transformation depends. This DSB task force believes that the overarching concept of early and continuous application of decisive combat effects, across the spectrum of contingencies, can link Joint Vision 2010 to the Services' emerging operational concepts. This concept – which the task force has called *Early and Continuous Combat Effectiveness* – is the principal theme of this summer study.

The ambitious objectives of Joint Vision 2010 imply a US military that can dominate future adversaries from the onset of any contingency. By contrast, for many contingencies today, effective US military capabilities require months of planning, force deployments to theater, and buildup and reconstitution of forces in theater. Early and continuous combat effectiveness is characterized by the ability to:

- Deliver potent military power within hours, anywhere in the world;
- Follow-up with more potent capabilities, including ground forces, within 24 hours; and
- Sustain and augment these forces, including establishing regional operating bases – some being sea based – even when there is limited local infrastructure.

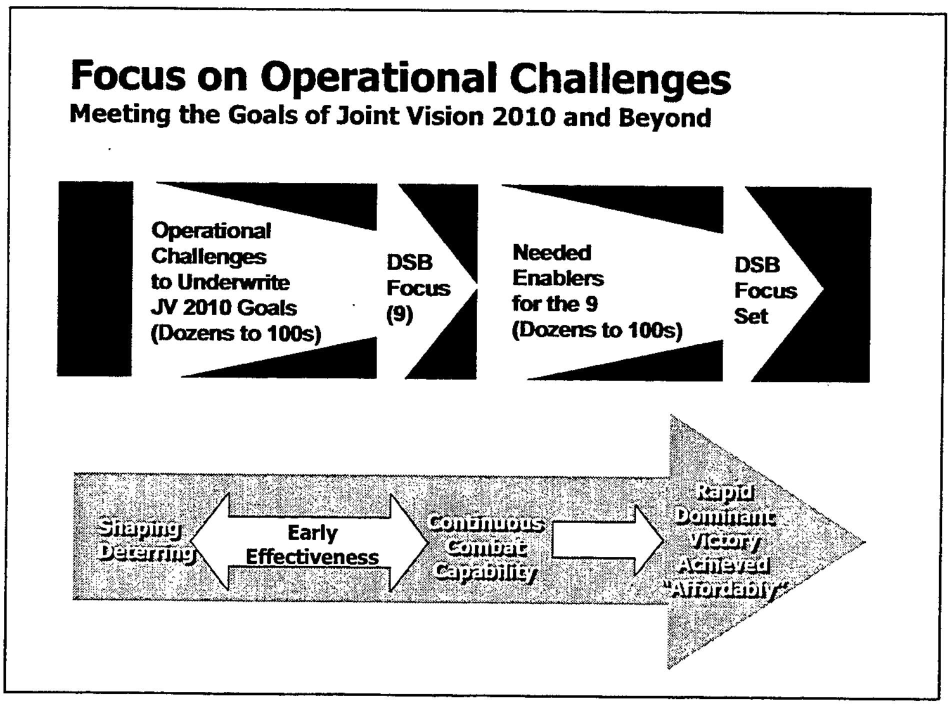
To achieve early and continuous combat effectiveness, US forces need to possess a wide range of capabilities, some in existence today, some planned for the future, and others that are not yet a part of the Department's plans. Core capabilities essential to achieving it are:

- Air, space, land, and sea forces that can deploy near-simultaneously from peacetime stations and operate from dispersed posture to minimize targets for enemy mass casualty weapons and quickly seize control of the situation;

- Joint doctrine guiding the concerted application of physical and psychological effects including fluid fires, rapid distributed ground maneuver, and focused information operations against opponents' strategic centers of gravity from the onset of hostilities;
- Agile ground forces that are much more strategically, operationally, and tactically mobile and that require less support than today's heavy forces but are far more potent than today's light forces; and
- Service support arrangements that maintain total asset visibility and make depot-to-user deliveries to minimize theater stocks, radically reducing support force deployments and reliance on large air and sea reception ports that are lucrative targets for mass casualty weapons and terrorism.

CRITICAL OPERATIONAL CHALLENGES

Underwriting Joint Vision 2010 requires addressing dozens to hundreds of operational challenges, as illustrated in the figure below. This DSB task force focused on nine critical operational challenges – one overarching challenge of early and continuous effectiveness and eight supporting and interlocking challenges that enable this central theme – and for each, identified critical enablers. As shown below, successful early entry is the first phase of continuous combat, but, in addition, the capability for early effectiveness is also a powerful shaping and deterrent force.



To move from today's capabilities to the dominance envisioned in Joint Vision 2010, the Summer Study task force searched for opportunities for large leaps to "revolutionary"

capabilities to bridge the gap. But in the end, the task force confirmed that while giant leaps are desirable, and DoD should continue to look for them, it is more likely that the road to revolutionary capabilities will be comprised of significant, evolutionary steps. Even so, it is essential to posit operational concepts that pull existing plans, structures, and capabilities into the future, spurring transformation and accommodating change. Defining such paths was the emphasis of the task force.

The eight supporting operational challenges enabling early and continuous combat effectiveness are: [1]

Assured Knowledge Superiority. Crucial to achieving full spectrum dominance is decision superiority, the ability to make better and faster decisions than America's opponents. The task force identified these key enablers:

- Overarching is the human dimension: a command and control structure that can meet the challenges of orchestrating globally dispersed joint and coalition forces and operate continuously with dynamic, integrated planning and execution. This system would exploit an integrated information infrastructure, planning tools, visualization aids, and reach-back. Through enhanced dissemination of commander's intent and shared situation awareness (horizontal as well as vertical), this structure would foster self-synchronization and robustness among forces.
- The foundation will be provided by a single integrated information infrastructure – robust and scalable – to serve all warfighters. It will heavily leverage commercial technology and systems and consist of multi-tier transport, distributed computing and processing, and intelligent software agents to manage the network and assist users.
- The information infrastructure will be supported by dynamically managed suites of sensor systems (space, air and surface-based) to provide multi-perspective, multi-phenomenology correlated perspectives.
- In addition to these three enablers – which are comparable to the three "grids" of the Network Centric concept – the DSB task force elevates information operations to a more prominent role. This includes protecting the information infrastructure, disrupting and deceiving enemy communications, and carrying out psychological operations.
- In order to project early decisive effects – that is, be effective within the first hours – it will be necessary to devote more attention to preparing the "battlefield." This will include exploiting and synthesizing analytical and visualization technologies to enable deep historical research, detection and continuous tracking of activity, and identification and targeting of key nodes.

Responsive Global Targeting. Early effectiveness depends on a highly responsive targeting capability able to direct fires from globally distributed shooters to hit the "right" target at the right time – when they are most vulnerable and valuable – and to fully integrate physical and

[1] Four operational challenges – coalition warfare, force and infrastructure protection, theater ballistic and cruise missile defense, and urban operations – are the topics of past or on-going DSB studies. As a result, they are covered in less detail. Annex A contains references to these and other DSB studies referred to in this report.

information effects. The enablers for this ambitious capability include, in addition to those above:

- Unambiguous combat identification and a registered (submeter accuracy) battlespace providing a common grid for targets, sensors, and shooters;
- Extended-range weapons with sub-meter precision that can engage from air, land, sea, and, eventually, space to destroy, disable, deny, or disrupt targets central to an opponent's ability to direct or support the operations of his forces or carry out attacks with mass casualty weapons; and
- "Soft kill" capabilities including offensive information operations and wide-area non-lethal weapons for dealing with targets while minimizing collateral damage.

Exploiting Littoral Areas. With an increasingly high percentage of the world's population located within coastal areas, many future military operations will be conducted in, near, or across these littoral areas. US forces need to be able to maintain control of the littoral battlespace, in close cooperation with coalition forces and local assets. Essential to such operations are:

- Air and space forces that can attack at extended ranges to find and disable an opponent's air defenses and disrupt or destroy functions of strategic and operational importance throughout the battlespace;
- Ground maneuver forces capable of disrupting enemy command and control, denying an enemy the ability to employ mass casualty weapons, and paralyzing opponents by moving so fast and so frequently that no enemy asset is safe and no counterstroke can be marshaled fast enough; and
- Naval surface and sub-surface forces capable of operating safely in littoral waters to conduct early and sustained offensive operations against an opponent's strategic centers and forces.

Flexible Inter- and Intra-Theater Mobility. Conducting early decisive operations requires rapid, seamless movement from peacetime bases into contingency operations. US forces need greatly improved inter- and intra-theater mobility – sea-based logistics, heavy theater airlift, and on-time delivery. Essential to such deployments are:

- Airlift-capable sea bases to reduce dependence on theater ports and airfields;
- Super-Short Takeoff and Landing (SSTOL) theater airlift capable of operating from sea-based ships and hastily prepared land sites;
- Fast shuttle sea lift from the sea base to the beach or small docks;
- Airlift-compatible land vehicles capable of all-terrain operations; and
- Fuel-efficient propulsion, recoverable sensors, and precision weapons to minimize logistical burdens.

Coalition Warfare. The Summer Study task force highlighted the importance of achieving a Combined Task Force that is fully integrated with coalition partners as an instrument of national power and that can be deployed, trained, and exercised as a team. Another DSB task force will soon issue a report with detailed findings and recommendations on coalition warfare.

Force and Infrastructure Protection. As stated in the 1997 DSB Summer Study report *DoD Responses to Transnational Threats*, "full dimensional protection" is essential. Such protection requires multi-layered protection for forces and facilities: a seamless joint architecture for protection from the theater level to the individual, including protection for non-military installations.

Theater Ballistic and Cruise Missile Defense. The US military needs continued investments in an array of capabilities to counter theater ballistic and cruise missiles that are finding their way into the hands of many potential adversaries. These capabilities include ground and sea based, point and wide area defense capabilities; ground and sea based, wide area defense against advanced cruise missiles; and an extended range air-to-air cruise missile defense.

Urban Operations. Urban environments are no longer avoidable for US and coalition forces. Although urban environments currently pose a challenge for targeting critical enemy nodes and forces, they cannot be allowed as a safe haven for these nodes and forces. The ability to control and dominate urban areas, the freedom of maneuver in urban areas, and the capability to discriminate between non combatants and combatants are critical enablers of effectiveness in many likely scenarios.

SUMMARY FINDINGS AND KEY RECOMMENDATIONS

The task force came to several overarching conclusions for underwriting Joint Vision 2010 and beyond:

- The capability for early entry, and then continuous dominant combat effects across the spectrum of conflict is central to Joint Vision 2010.
- Key operational enabling capabilities include assured knowledge superiority, the ability to out-innovate the competition, and the ability to dominate in information operations, both offensive and defensive.
- It is essential to leverage and protect US asymmetric strength and to have integrated operations and logistics. Quality people with superb training will be even more important in 21st century operations.

The primary task force recommendation is that Early and Continuous Combat Effectiveness be a major organizing construct for the Department's pursuit of Joint Vision 2010. It addresses a central and critical challenge facing the US military and will provide needed focus for the transformation to a 21st century force.

The task force has identified a set of recommendations, shown in the following tables, that form the building blocks for an effective early entry and continuous combat capability. With each recommendation, an implementing organization is identified as well as an estimate of the level of investment required where appropriate. Many of the recommendations have low to

modest risk, with potential payoff within the next decade. These recommendations include an integrated information infrastructure, continued progress in chemical and biological warfare defense, advanced munitions, bomber upgrades, Trident conversion, and a family of lightweight vehicles, among others.

Other recommendations focus on development endeavors with longer-term payoff and, in many cases, with higher investment costs. The task force recognizes the significant resource implications of the long-term recommendations. To pay for these new developments, which are vital to underwriting Joint Vision 2010, the Department needs to reprioritize its research and development and procurement programs from 20th-century hardware to 21st-century needs. In some cases these longer-term initiatives reflect programs that are in some stage of development or definition but deserve more attention and support, such as an expanded MPF-2010; heavy lift, high altitude endurance, unmanned aerial vehicle (HAE UAV) systems; and the space operations vehicle. Others are suggestions for future replacement systems, such as the SSTOL and fast shuttle intra-theater sea lift. The task force believes that implementing these recommendations is achievable within the Department's long-range budget plans, but only if there is a major shift in priorities and clear recognition that implementing Joint Vision 2010 will not be cheap or easy.

RECOMMENDATIONS

Early and Continuous Combat Effectiveness

- Define and establish joint force packages of agile, lethal, survivable early deploying combat forces (*Joint Staff, US Atlantic Command, Services*)
- Develop a family of lightweight, energy-efficient vehicles (*Army/Marine Corps/DARPA, $500 million*)
  - Lightweight armored vehicle
  - General-purpose wheeled vehicle less than half the weight and cube of the High-Mobility Multi-Purpose Wheeled Vehicle (HMMWV) – commercially based
- Program the heavy bomber upgrades to create precision strike platforms (*Air Force, $1 billion*)
  - Small, precision munitions
  - Dynamic mission planning
  - Command and control (C^2) connectivity
  - Forward-based support
- Convert four Trident submarines to high-capacity, precision-strike platforms (*Navy, $1.52 billion*)
- For the longer term, pursue a space operations vehicle and develop common aero vehicle payloads (*Air Force, several billion in 2000-2015*)
- Field the family of advanced munitions in needed numbers (*USD/A&T, $500M-$1B*)
  - Current development programs
  - New advanced munitions

Assured Knowledge Superiority

- Explore – through experiments – command and control structures, processes, and technologies that enable: (*Joint Staff/US Atlantic Command, $30 million annually*)
  - Immediate and continuous operations on the move
  - Dispersed forces and dispersed C^2
  - Shared real-time understanding of situation and commander's intent
  - Synthesize data into knowledge, pushed to and pulled by users
- Develop a single Integrated Information Infrastructure for battlespace awareness, logistics, targeting information, and command and control based on: (*USD/A&T, $1-2 billion*)
  - Exploiting commercial internet technologies and practices
  - Integrating legacy C^4ISR systems
- Protect superiority with enhanced information operations (*Joint Staff/ NSA, $100 million*)

RECOMMENDATIONS

Responsive Global Targeting

- Integrate space-, air-, and surface-based sensors and associated tools for exploitation and management (*ASD/C^{3}I, $100 million annually*)
  - Focus additional sensor development on continuous coverage and obscured targets (foliage, underground, urban)
- Implement a "common-grid" to register targets, sensors, and weapons with a target location error of less than one meter (*ASD/C^{3}I, $100 million*)
- Develop effective, dynamic planning tools for (*Joint Staff/Services/ DARPA, $50 million*):
  - Seamless planning and execution of continuous operations
  - Targeting precision weapons and target allocation
- For the longer term, expand high altitude endurance UAV plans for heavier lift, multi-mission operations (*Air Force*)

Flexible Survivable Intra-Theater Mobility

- For the longer term, expand MPF-2010 to include a ship capable of functioning as an inter-theater airlift base and a highly mobile offshore base, with a 600 foot runway (*Navy*)
- As the eventual C-130 replacement, initiate development of a sea and land-based capable intra-theater SSTOL air lifter (*Air Force/DARPA*)
- Replace current lighterage with a fast shuttle intra-theater sea lift (*Navy*)

Exploiting the Littoral Battlespace

- Maintain commitment to improved mine countermeasure capabilities (*Navy, $438M in FY2000-2005*)

In summary, achieving a capability to apply early and then continuous dominant combat effects across the spectrum of conflict is the most difficult and central of the many operational challenges associated with underwriting Joint Vision 2010. The task force believes that the Department of Defense is capable, both technologically and financially, of building a dominant early-entry capability that allows for continuous combat power from "the first day" by obtaining effective operational capabilities in the areas highlighted above. Implementing the needed mix of initiatives will be a complex undertaking, exacerbated by the many competing demands for resources.[2] The task force recommends the following overarching tasks to the Department's leadership:

Secretary of Defense lead implementation by:

- Guidance emphasizing creation of forces that achieve early and continuous combat effectiveness
- Directing implementation of specific initiatives

Chairman, Joint Chiefs of Staff:

- Build the needed operational architecture for an early and continuous combat capability
- Validate with a Joint Early Entry Force established for experimentation

Under Secretary of Defense for Acquisition and Technology:

- Prioritize the research and development and procurement accounts to ensure emphasis on these operational challenges

Underwriting Joint Vision 2010 is a significant challenge. But it is within the Department's ability to accomplish. *At its core is the theme of early and continuous combat effectiveness across the spectrum of conflict.* Focusing on this challenging concept should help guide the Department to a superior 21st century military capability, with full spectrum dominance – the central theme of Joint Vision 2010.

[2] Annex B offers a more detailed discussion of cost, affordability, and acquisition strategy issues.

CHAPTER 1.

Introduction

Today the situation is far more complex ... with a wider range of conflict from peacekeeping to major theater wars, a wider range of adversaries from rogue nation states to transnational adversaries and terrorists, and the widespread proliferation of military and commercial technologies.

CHAPTER 1.

Introduction

At the request of the Chairman, Joint Chiefs of Staff (CJCS) and the Under Secretary of Defense for Acquisition and Technology (USD(A&T)), the Defense Science Board 1998 Summer Study task force addressed integrating capabilities underwriting Joint Vision 2010 and beyond. More specifically, as stated in the terms of reference, the task force focused on "how new [operational] capabilities, operational concepts, and different force characteristics can be developed and integrated to underwrite Joint Vision 2010."[3]

The work of the Summer Study task force builds on recent Defense Science Board (DSB) studies as shown in Figure 1 below. The task force reviewed the findings and recommendations of those studies and applied them to this effort, with emphasis on highly relevant technologies and operational capabilities that have not yet been fully assimilated by the Department of Defense (DoD). At the same time the task force assessed the continuing evolution of technologies and capabilities shown in the top right block as a basis for evaluating what emerging technologies and capabilities can be most effectively used to produce a dominant force for the 21st century.

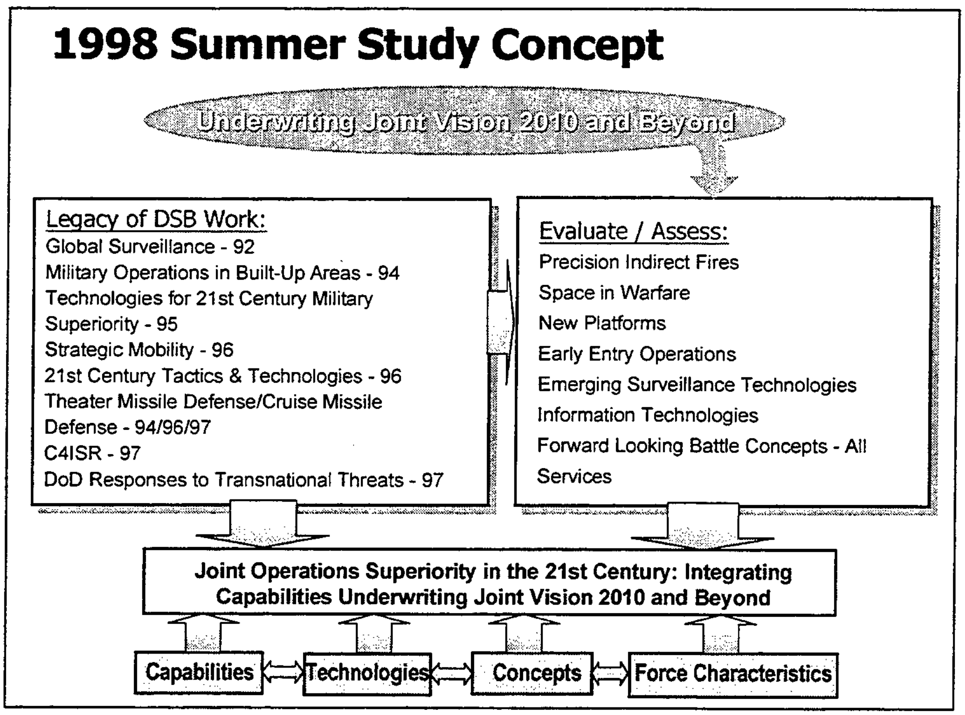


Figure 1. 1998 Summer Study Concept

Integrating this legacy of DSB studies with the many emerging technologies and capabilities, the task force identified new capabilities, new ideas, and new emphases which help to underwrite

[3] Annex C contains the complete Terms of Reference for the Defense Science Board 1998 Summer Study.

Joint Vision 2010 and beyond and which provide the basis for new force characteristics. It is important to note that the task force found it neither necessary nor desirable to invent new operational concepts. There are exciting and innovative concepts being developed by the military Services and provided in Joint Vision 2010 – the Army After Next, the Air Expeditionary Forces, and Operational Maneuver from the Sea. Each of these overarching concepts is intended to shape military operations in the 21st century. The task force analysis and recommendations are built on these operational concepts applied to 21st century warfare.

CHANGING ENVIRONMENTS AND THREATS

As the nation moves toward the 21st century, the United States faces a highly dynamic international environment within which its military forces will operate. The cold war period was one of multi-polar adversaries and allies and was characterized by reasonably clear delineation between protecting interests overseas, protecting the borders of the homeland, and maintaining security within the borders. Today the situation is far more complex, as Figure 2 portrays.

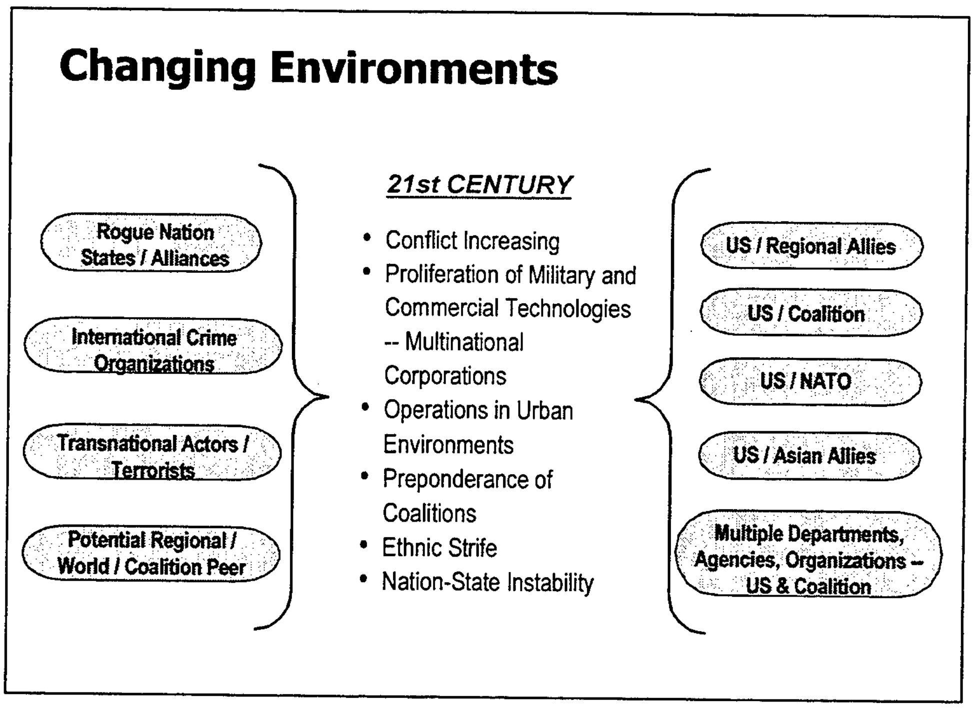


Figure 2. Changing Environments

Today, adversaries are more diverse. Future adversaries might include the potential emergence of either a regional or world peer, or a coalition with similar capability. While wars in the traditional sense may be decreasing, conflicts are increasing. The US military will operate in an environment where coalitions are a fact of life. America's adversaries have increasing access to threatening asymmetric capabilities to offset US and coalition military prowess. It will be no longer possible to bypass urban environments in the conduct of military operations. And there is an increasing linkage between force projection, overseas force protection, infrastructure security, and force protection at home.

The conduct of military operations is further complicated by the fact that American military forces will need to work not only with coalitions and allies but also with multiple departments and agencies both within the US government and within foreign governments. Moreover, the political environment – both foreign and domestic – has an impact on military operations at every level, far more profoundly than in the past. In short, the 21st century environment will be more diverse, more complex, and potentially more threatening.

THE TASK FORCE AND REPORT

To address this large and challenging issue, the Defense Science Board task force team of members and government advisors represented a wide range of technical and operational disciplines with subject expertise in all aspects of military operations.[4] The task force divided into three Joint Vision Teams that focused on a subset of the critical challenges discussed in this report. The teams investigated these challenges against the entire spectrum of warfare, evaluating the implications from peacekeeping operations to major theater war, and put considerable emphasis on identifying key technologies and capabilities where investments in research and development would be most prudent for the Department.

The chapters that follow present the integrated results of the task force deliberations. Chapter 2 begins with a summary of elements of Joint Vision 2010 as it relates to the task force mission. Chapters 3 through 5 discuss the critical operational challenges required for underwriting Joint Vision 2010. Chapter 3 focuses on the core challenge of early and continuous combat effectiveness. Chapter 4 covers four key enabling challenges: assured knowledge superiority, responsive global targeting, inter- and intra-theater mobility, and exploiting the littoral battlespace. Chapter 5 continues with four supporting operational challenges: coalition warfare, force and infrastructure protection, theater ballistic and cruise missile defense, and urban operations. The final chapter summarizes the task force recommendations and actions for the Department's leadership.

A SPECIAL NOTE

The 1997 Summer Study had much to say about the 21st century transnational threat. This year's task force continues to emphasize those issues, recognizing today's volatile international environment and the impact of that environment on US military and diplomatic operations. In light of the August 1998 embassy bombings in Kenya and Tanzania that occurred as the Summer Study deliberations were underway, the task force felt it important to emphasize several recommendations from the 1997 study related to overseas infrastructure and personnel protection:

- Reinforce the Director, Central Intelligence/Department of Defense initiative to create the Transnational Threat Information Infrastructure.
- Conduct overseas coalition exercises that emphasize protection against weapons of mass destruction and consequence management.

[4] A list of task force members is in Annex D.

- Stand up a second Chemical Biological Incidence Response Force (CBIRF), capable of operations in the continental United States (CONUS) and overseas.
- Take further steps to assure that transnational threats have minimal impact on US ingress/egress deployments.

The first recommendation provides an important information infrastructure. The Transnational Threat Information Infrastructure is a two-way, multi-level, secure global network that can link from the lowest to highest levels of command and to other sources of information such as local police stations. The network would provide a means of exchanging information on transnational adversaries and their actions. The task force believes that it is important to conduct coalition exercises that emphasize protection against weapons of mass destruction and consequence management issues. In addition, the Department should stand up a second Chemical Biological Incidence Response Force. There is currently only one such force in the United States today, a Marine Corps unit based in North Carolina. This superb capability should be expanded, using the National Guard, with the ability to support operations in both the United States and overseas. Finally, the task force urges DoD to take further steps to assure that the United States can continue to have freedom of movement to and from global conflicts as required.

CHAPTER 2.

Joint Vision 2010

Joint Vision 2010 achieves full-spectrum dominance through the five tenets of dominant maneuver, precision engagement, full-dimensional protection, focused logistics, and information superiority. ... But the greatest power of Joint Vision 2010 lies in the linkages and the synergies between these thrusts.

CHAPTER 2.

Joint Vision 2010

Joint Vision 2010 is the conceptual template for how America's Armed Forces will channel the vitality and innovation of our people and leverage technological opportunities to achieve new levels of effectiveness in joint warfighting. ... [T]his template provides a common direction for our Services in developing their unique capabilities within a joint framework of doctrine and programs as they prepare to meet an uncertain and challenging future.[5] Joint Vision 2010 builds on America's core strengths of high quality and highly trained people, technologically superior equipment, high standards of readiness, and leadership development.

The central theme of Joint Vision 2010 is full spectrum dominance – dominance at all levels of conflict, across the full spectrum of warfare. This is achieved through the four operational concepts of dominant maneuver, precision engagement, focused logistics, and full-dimensional protection, all supported by information superiority. These five tenets are the basis for operational superiority in the 21st century:

- *Dominant Maneuver* uses widely dispersed joint air, sea, land, and space forces in rapid strike operations. It is based on the multidimensional application of information, engagement, and mobility capabilities to position and employ these forces.
- *Precision Engagement* consists of a system of systems that enables forces to quickly locate the objective or target, provide responsive command and control, generate the precise desired effect, assess results, and retain the flexibility to reengage with precision when required.
- *Full-Dimensional Protection* is the ability to protect forces and facilities at all levels from adversary attacks, without impeding freedom of action during all phases of conflict.
- *Focused Logistics* enables agile battlefield operations through the ability to provide rapid crisis response, track and shift assets even while enroute, and deliver tailored logistics packages and sustainment at all levels of operations.
- *Information Superiority* is the underlying key, offering the ability to collect, process, and disseminate an uninterrupted flow of critical information while exploiting or denying an adversary's information flow.

This vision drives the emerging technologies, capabilities, and operational concepts shaping defense capabilities in the 21st century.

[5] *Joint Vision 2010*, Chairman of the Joint Chiefs of Staff, July 1996.

During the Cold War, the concept of marginal superiority was an accepted approach to warfare. Under the theory of marginal superiority, the United States and its coalition partners would have enough superiority in enough areas to ultimately achieve overall campaign objectives, though with individual battle losses and some casualties during the course of the conflict. This concept is illustrated in the lower left portion of Figure 3. The Gulf War introduced a new and simple strategy: dominate the individual battles from the outset to quickly win the campaign. Across the scales of level of conflict and the time in conflict, the Gulf War established that the United States and its coalition partners could indeed dominate part of the time and at some level of conflict. That is, with time for force buildup, the forces dominated the battlespace and prevailed at a high level of conflict with minimum casualties.

Joint Vision 2010 embodies this Gulf War strategy, as shown in the right portion of Figure 3, extending dominance to all levels of conflict, across the entire spectrum of warfare – major theater war, small scale conflicts, and peacetime engagement – with the objective of achieving dominance early in a conflict. Ultimate superiority, as shown in the lower right quadrant, is such visible *dominance* that potential adversaries are deterred from actions that could precipitate conflict with the US and its allies.

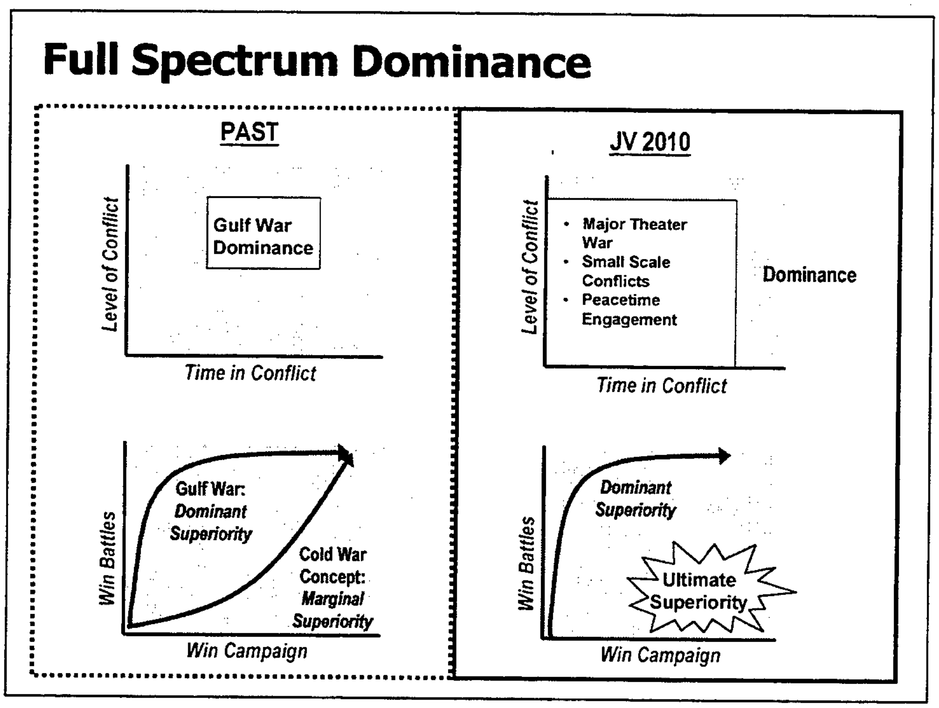


Figure 3. Full Spectrum Dominance

To achieve the level of dominance envisioned in Joint Vision 2010 requires addressing a wide range of challenges. But it is also important to note that there are important challenges involved in simply maintaining the dominance that the United States had during the Gulf War. Over time, these military capabilities can erode. The Department of Defense needs to take action to protect current superior capabilities from such erosion.

Superiority will be challenged by increasing international availability of state-of-the art commercial products and services, particularly in the area of information superiority. Potent military arms are increasingly available on the world market. Furthermore, there are straightforward, logical countermeasures to some of the superior capabilities that were important to the United States during the Gulf War. Adversaries have watched US strengths, demonstrated in Desert Storm, and can be expected to identify vulnerabilities and use countermeasures. Example capabilities that need to be protected from erosion include: stealth, space navigation, telecommunications, space and airborne surveillance, night vision, electronic combat, precision weapons, simulation and training aids, and the reliability and availability of the Global Positioning System (GPS). GPS is particularly important because many capabilities essential to full spectrum dominance depend on the availability of GPS to the United States and its coalition partners.[6]

In the area of telecommunications, it will be particularly difficult to maintain information superiority with widespread availability of commercial sources for information. Figure 4 shows commercial satellite launches anticipated from 1998-2008, adding up to more than 1,700 commercial satellites in orbit over the next 10 years. A significant number of nations will be operating imaging satellites by the year 2008. This means that the United States' future advantage needs to come from superiority in using information – that is, "knowledge superiority." Knowledge superiority and decision superiority are capabilities where the United States can continue to dominate.

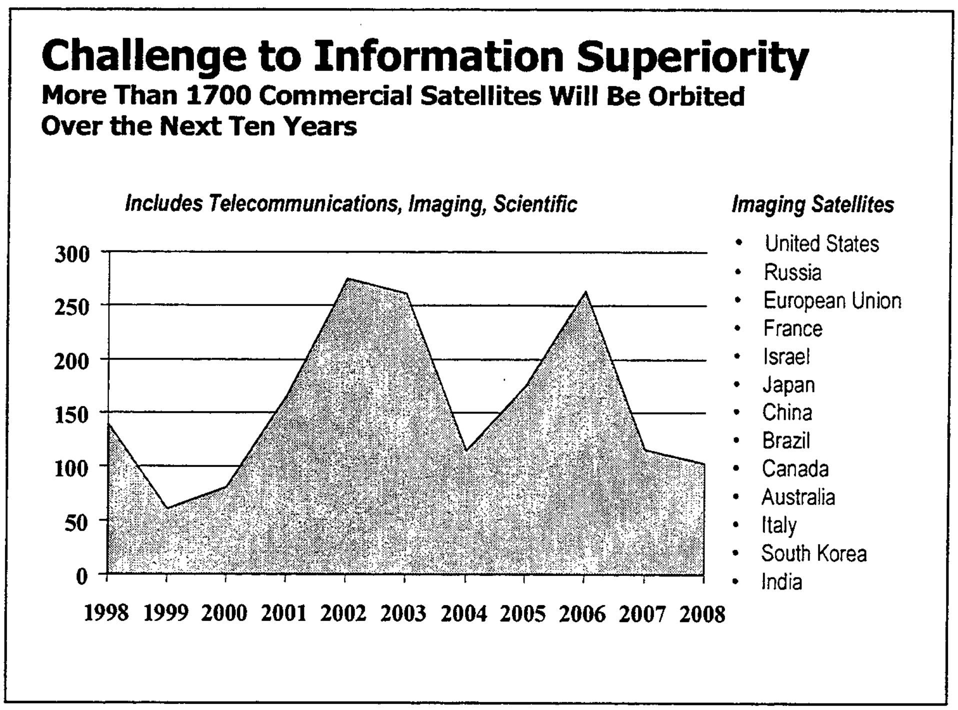


Figure 4. Challenge to Information Superiority

[6] Annex E addresses the important challenge of GPS vulnerability.

Joint Vision 2010 achieves full-spectrum dominance through the five tenets of dominant maneuver, precision engagement, full-dimensional protection, focused logistics, and information superiority. These concepts are well rooted in proven principles beginning with the classical principles of war: offensive mass, economy of force, movement, unity of command, security, surprise, and simplicity. It also builds on a series of enduring operational themes: increased precision, lethality, protection, command and control, and awareness; and decreased time, casualties, and collateral damage.

But the greatest power of Joint Vision 2010 lies in the linkages and the synergies between the thrusts, as illustrated in Figure 5. For example, focused logistics both benefit from and make dominant maneuver and precision engagement possible. The same is true of the relationship between full-dimensional protection and the other attributes since full-dimensional protection means freedom from enemy interference while dominant maneuver means freedom to operate anywhere, anytime. All depend on and are supported by information superiority.

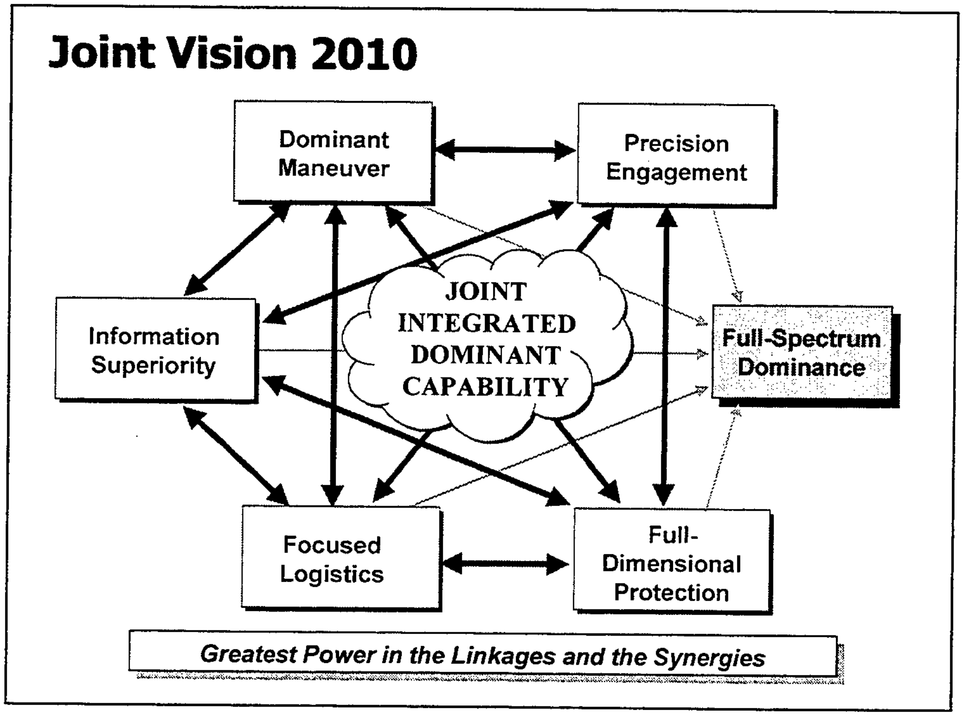


Figure 5. Joint Vision 2010

To move from today's capabilities to the type of dominance envisioned in Joint Vision 2010, the DSB task force searched for "revolutionary" capabilities to bridge the gap. But in the end, the task force found that while such giant leaps are desirable, and DoD should continue to look for them, it is more likely that the road to revolutionary capabilities will be comprised of significant, evolutionary steps, as illustrated in Figure 6. Defining such paths was the emphasis of the task force.

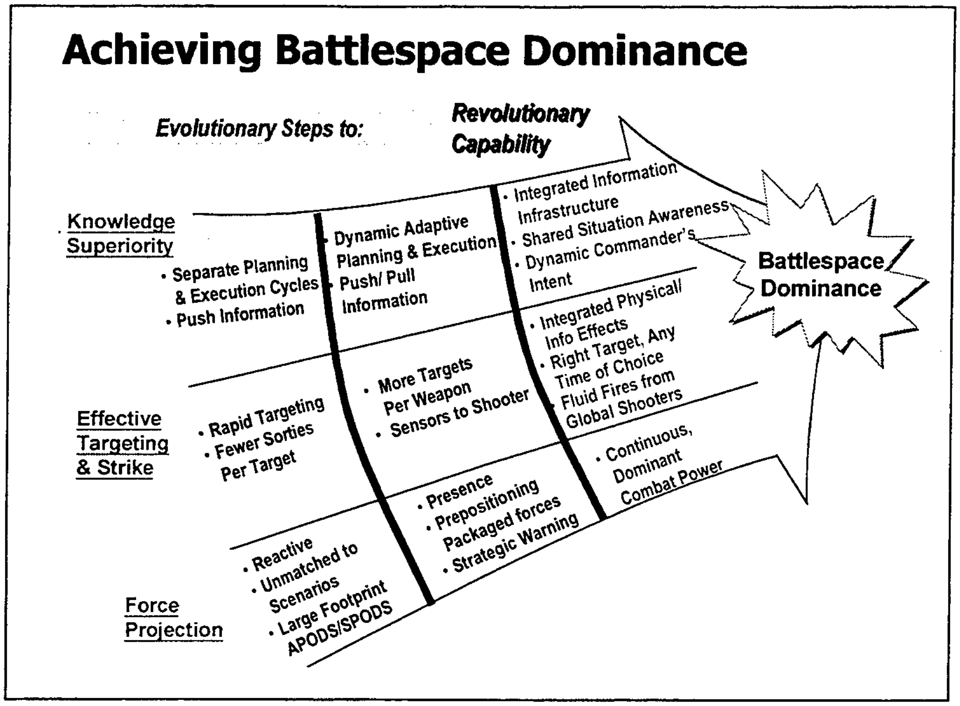


Figure 6. Achieving Battlespace Dominance

In the area of knowledge superiority, for example, DoD's capability moves from the separate and lengthy planning and execution cycles of today, to a more continuous and dynamic process. This revolutionary capability is one where information flow allows the commander to formulate and disseminate intent based on up-to-date knowledge of the existing situation in the commander's sphere of the battlespace. Similarly, effective targeting and strike evolves from successful efforts to destroy targets with fewer sorties and weapons, to the capability to have the precisely desired impact on any target, any time. In the area of force projection, today's forces are reactive, require extensive tailoring and adaptation to match to scenarios, and require a large support infrastructure. This can be improved with better presence, prepositioning, and strategic warning. But the ultimate goal is continuous, dominant combat power from early in an operation for whatever type of operation is required. These evolutionary steps are the most certain path to a revolution in military force capability.

The 21st century warfare environment is often described in terms of asymmetrical capabilities and strengths on the part of America's opponents. But the United States also has important asymmetric capabilities. First, the US military possesses the most skilled and highest quality individuals who are superbly trained. Joint Vision 2010 will put increasing demands on these individuals because more will be expected out of each person and combat element. The United States, more than any other country, possesses global knowledge, global presence, and can project power anywhere on earth. The United States is also a world leader in the rapid-paced domain of information systems. America enjoys superiority in the areas of telecommunications, space and airborne surveillance and navigation, electronic combat, GPS usage, night vision, and simulation and training aids. With increased and innovative use of commercial practices and technologies, DoD can stay the world leader. Perhaps most important is the virtually unique ability of the United States to apply highly effective joint forces worldwide using high lethality

precision weapons, operational stealth, battlespace maneuverability, and a wide menu of anti-armor capabilities. These asymmetric capabilities will be key underpinnings for implementing Joint Vision 2010. Significant DoD attention is needed to preserve US strengths in these areas.

Underwriting Joint Vision 2010 requires addressing dozens to hundreds of operational challenges and dozens to hundreds of enablers for any set of these challenges. It is a massive set of technical and operational challenges. From that set, this task force focused on nine enablers: one overarching challenge and eight supporting and inter-locking enablers, shown in Figure 7 below. The focus on this set emerged from the combination of realistic technology opportunities, assessed uncertainties and risks in implementation, and the potential operational impacts on US force characteristics toward achieving a dominant future combat capability.

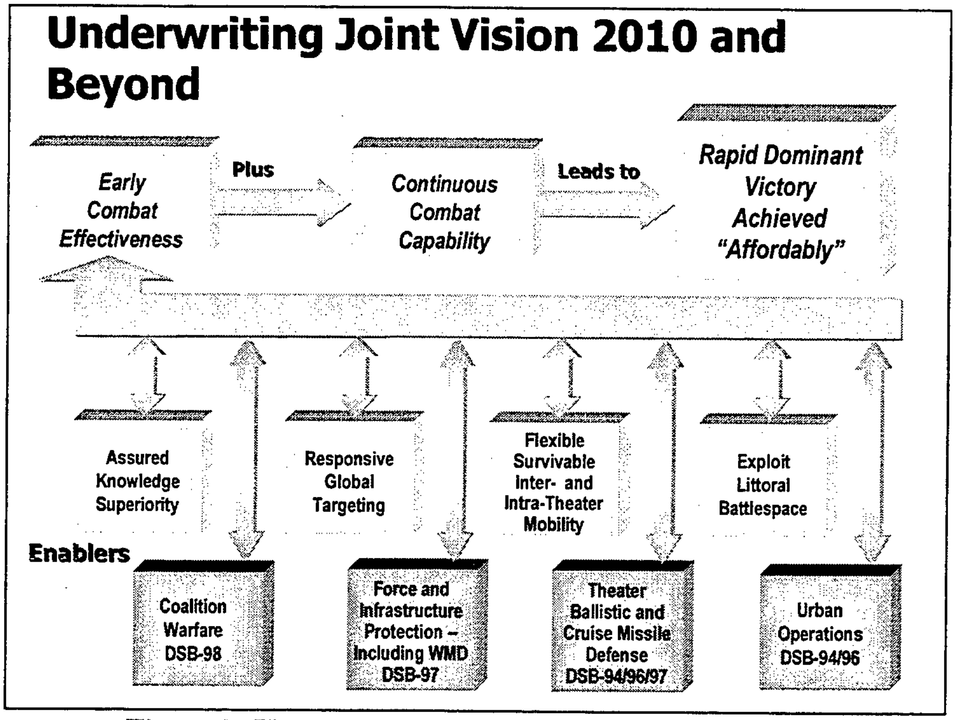


Figure 7. Underwriting Joint Vision 2010 and Beyond

The overarching theme of this study is the capability to project effective, joint multi-dimensional combat power in the first hours of conflict. This embraces the spectrum of operations from shaping and deterring prior to conflict to post conflict operations. Adding to early combat effectiveness a continuous combat capability leads to an affordable means – in casualties, cost, and time – to achieve rapid dominant victory. It is important to note, as the two-way arrows in Figure 7 show, each of the operational challenges are linked and there are important synergies derived by addressing these challenges as an integrated system of systems. For example, to enable responsive global targeting requires a global knowledge system providing, among other things, clear commander's intent, precise battlespace understanding, timely targeting data, and command and control. Exploiting the littoral battlespace requires new capabilities for intra-theater mobility. Chapter 3 addresses the overarching theme of early combat effectiveness and enabling early entry forces. Chapters 4 and 5 discuss the eight supporting challenges.

CHAPTER 3.

Early and Continuous Combat Effectiveness

The DSB task force has focused on the central challenge in underwriting Joint Vision 2010: the capability to apply early and continuous combat effects across the spectrum of conflict.

CHAPTER 3.

Early and Continuous Combat Effectiveness

Joint Vision 2010's concepts of precision engagement, dominant maneuver, and full-spectrum dominance, enabled by information superiority, grew naturally from the overwhelming tactical dominance achieved by US and coalition forces during the 1991 Persian Gulf War. Bringing precise, focused combat power to bear early in a distant, overseas contingency and providing continuous combat effectiveness is essential to the overarching theme of dominance.

Early and continuous combat effectiveness is characterized by the abilities to:

- Deliver potent military power within hours anywhere in the world;
- Follow-up with more potent operations, including ground forces, within 24 hours; and
- Sustain and augment these forces, including establishing regional operating bases – some being sea based – even when there is limited local infrastructure.

This chapter provides a coherent context for developing forces that can provide early and continuous combat effectiveness. Figure 8 illustrates this context. The top of the chart defines expected evolutionary improvements in the operational capabilities of US military forces needed to meet this challenge, with the upper right box defining the goal for 2010 and beyond.

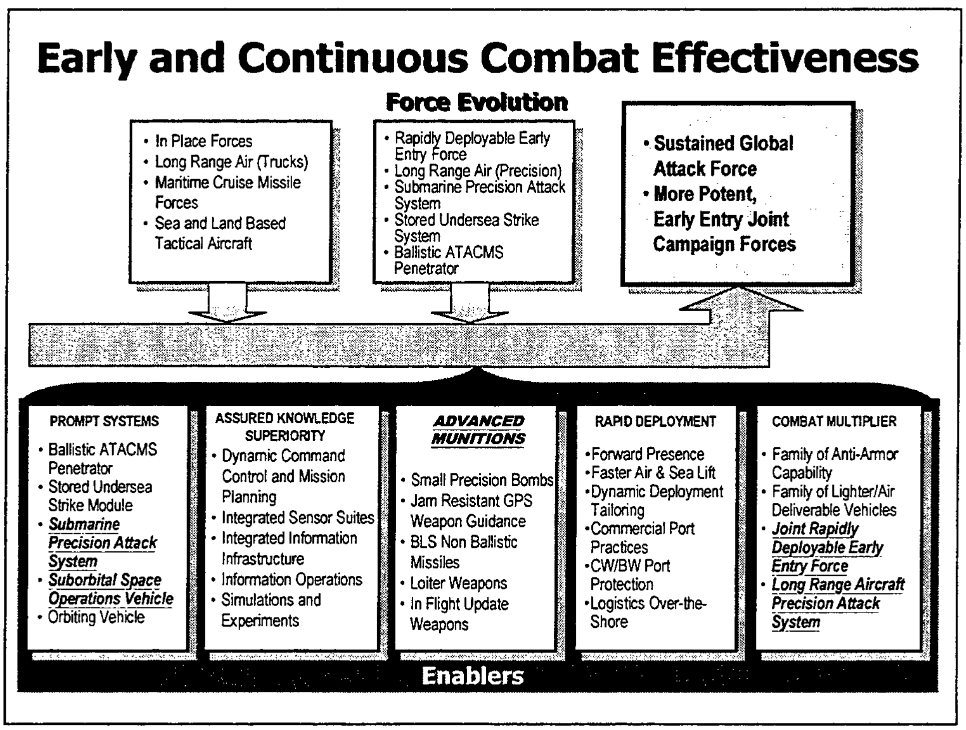


Figure 8. Early and Continuous Combat Effectiveness

The bottom of the chart shows some necessary enabling capabilities and technologies in five functional areas: prompt systems, assured knowledge superiority, advanced munitions, rapid deployment, and combat multipliers. These five areas are linked and interdependent. For example, precision engagement by any platform and munition is dependent on knowledge superiority. Prompt systems support rapid early and decisive application of precision force. As Figure 8 shows, the enabling capabilities are many; only those highlighted are discussed in this chapter – Joint Rapidly Deployable Early Entry Forces, Long-Range Aircraft Precision Attack System, Submarine Precision Attack System, the Suborbital Space Operations Vehicle and advanced munitions. While this chapter focuses on forces and systems that enable early and continuous combat effectiveness, the eight other operational challenges, which are themselves key enablers, are discussed in Chapters 4 and 5.[7]

TIME SPAN TO FIRST IMPACT

To frame the early entry aspect of this challenge, it is useful to look at the early entry forces currently available to the US military and how those forces can be enhanced. Current capabilities are limited to on-scene or forward-presence forces. These can frequently provide a deterrent effect or initial crisis response. While they may curtail or cap a crisis, conflicts can erupt in locations where US forward presence forces are not situated or where the scale of the conflict requires decisive campaign-level capabilities.

As depicted in Figure 9, there are measures that can be taken early, such as repositioning global assets, selected information warfare operations, and certain special forces' missions. However, the ability today to bring immediate strikes to bear depends on having credible strategic warning. Based on that warning, the degree to which strike forces can be predeployed in or near the potential theater drives the time to first combat. Under the best of circumstances, vital targets could be attacked several hours after the decision to act by sea- and land-based tactical aircraft already within range of the more time-urgent or critical targets. It is more likely, however, that it would require several days to bring offensive strike forces together in theater; even longer, perhaps three to five days, for light early elements of a ground force to arrive; and significantly longer for greater capabilities.

Responsiveness can be improved with added capabilities, available in the near term. A Rapidly Deployable Early Entry Force could cut days off the time the United States is able to begin ground operations as well as bring greater combat capability – to include anti-armor capability – against a full range of 21st century combat environments. This early entry force would employ agile fighting and transport vehicles, a family of rapidly-deployable anti-armor systems, and greatly enhanced command, control, and communications.

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7 Volume II contains supporting reports on many of the other enabling capabilities and technologies that are listed in Figure 8 and in subsequent chapters.

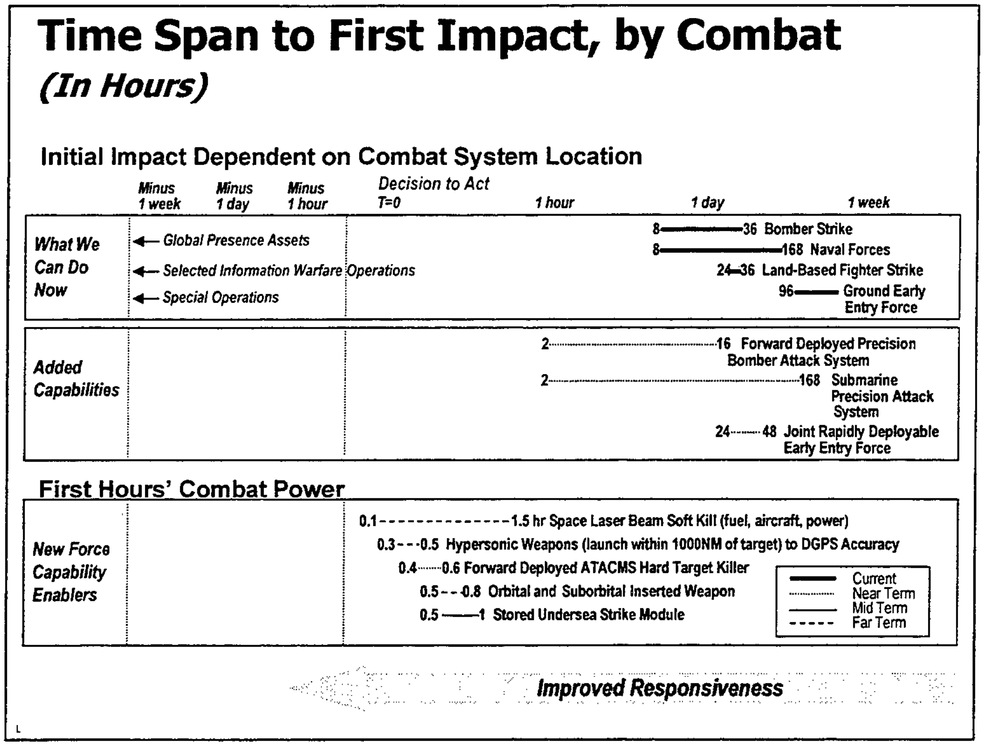

Figure 9. Time Span to First Impact

The ability to deliver prompt, long-range, non-nuclear, precision fires over intercontinental distances can also improve responsiveness. With modest investments, DoD can convert existing heavy bombers to high capability precision attack systems. A Submarine Precision Attack System could, if within range, attack a mixture of fixed and tactical mobile targets within a couple of hours after a decision to act – and could be predeployed near the theater without alerting enemies to the likelihood of imminent attack. A similar concept is the Stored Undersea Strike Module described in Volume II. It is an uninhabited underwater missile launch platform that could be towed to an area of interest by a nuclear submarine, moored, and then remotely operated to provide prompt precision fires during the first hours of a conflict. Key to such early targeting is the availability of a day/night, all-weather, global surveillance capability with continuous surveillance. A space-based synthetic aperture radar system with the ability to detect and track moving tactical targets, such as armor or missile transporters, could provide such a capability.

It is possible to strike even sooner and more decisively by adding new force enablers, as indicated in the lower half of Figure 9. There are a number of medium- to high-risk technical approaches, such as space-based directed energy and kinetic weapons and surface-launched hypersonic weapons, that if successfully developed, could provide the capability to strike within minutes of a decision to do so. One example is the Suborbital Space Operations Vehicle (SOV) carrying the Common Aero Vehicle (CAV). Reusable SOVs, based in the continental United States, could be maintained in a ready condition and launched on short notice. The CAV could carry a variety of precision-guided weapons, designed to attack a wide range of targets. Against fixed or stationary targets, differential GPS guidance would enable high probabilities of kill using small precision-guided weapons. Laser radar, or a millimeter-wave radar guidance linked

to off-board sensors through the Integrated Information Infrastructure, could allow attacks on moving targets using weapons such as the Low Cost Autonomous Attack System (LOCAAS). The suborbital trajectory followed by the Common Aero Vehicle enables attacks anywhere in the world within tens of minutes of launch. Although this system requires long-term development, other enablers might be available in the shorter term.

These capability enablers would close the time gap between the decision to strike and force application from days to minutes and could provide the critical first contribution of dominant superiority in any theater.

JOINT RAPIDLY DEPLOYABLE EARLY ENTRY FORCE (JRDEEF)

Future adversaries are unlikely to allow for a protracted build up of military forces necessary to protect vital US and coalition interests. As a result, there is a need for DoD to add a joint rapidly deployable early entry force capability, able to engage in both defensive and offensive combined arms operations within 24 hours.

Examples of scenarios where rapidly deployable early entry forces are essential include an aggression by a regional peer and a strike to secure and destroy a weapons-of-mass-destruction capability. In both cases, today's ground forces cannot provide the agile, potent, and survivable complement to the long-range precision firepower needed in the first hours and days of such crises. Today's light forces are too vulnerable and insufficiently potent to engage in a combined arms conflict. And today's heavy force is too bulky to be rapidly deployed in a crisis unless heavy stocks and equipment are pre-positioned in the right location. Rapidly deployable and decisive early entry forces need to be designed specifically for early crisis response but also will need to have high utility in the many and diverse kinds of stability and support operations which have become commonplace today, and may increase in the future.

Figure 10 shows a schematic of the early entry force envisioned to support Joint Vision 2010 and beyond. The JRDEEF could consist of airlift, tactical air and naval forces, and ground forces. The first on-scene element would be a Rapid Response Liaison and Combat Support (RRLCS) force to coordinate initial US support with the efforts of coalition partners and strategic and tactical air units. This would be followed by a Light Infantry Response (LIR) force – Army and/or Marine Corps – to protect vital assets needed for early entry, and a Light Mechanized Strike (LMS) force capable of a wide range of early operations.[8] This force can be deployed independently or in conjunction with forward presence forces. As an independent force, the joint early entry strike force can deploy to permissive environments as a demonstration of US resolve to deter a crisis, to facilitate stability, or to conduct decisive operations against a belligerent. The JRDEEF can also be used to reinforce the efforts of a forward-deployed enabling force conducting forcible entry operations.[9]

[8] Annex F contains further description of the Joint Rapidly Deployable Early Entry Force.

[9] Annex G and Volume II contain analytic analyses and modeling results, developed by RAND, for a notional 21st century force engaged in a combined arms conflict.

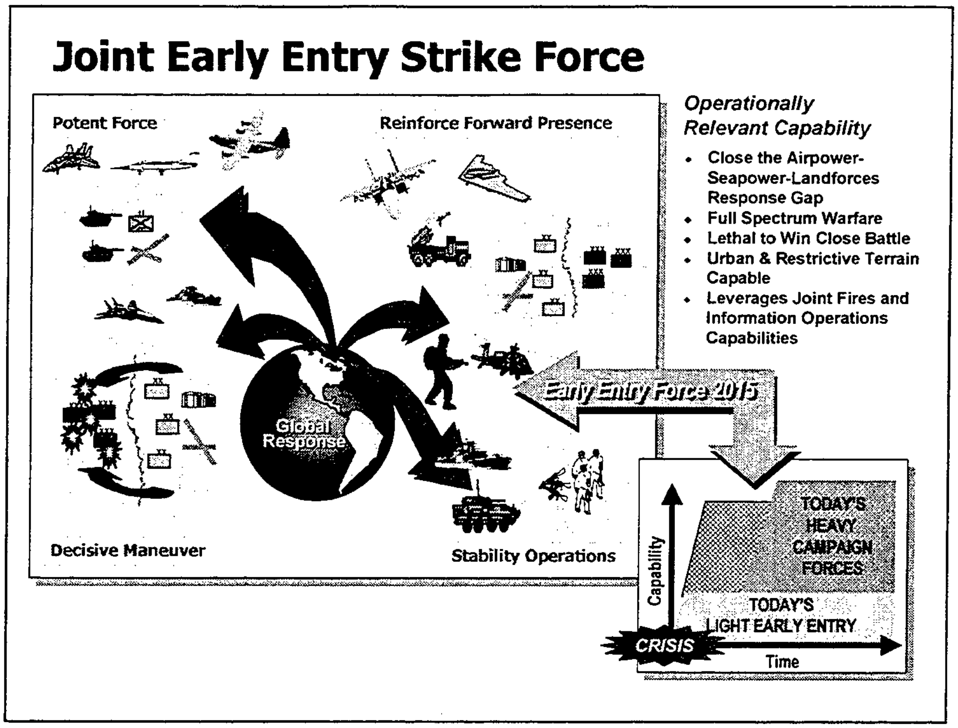

Figure 10. Joint Early Entry Strike Force

ENABLING TECHNOLOGIES

The successful development of this force requires continued and increased support for technologies and systems in a number of key areas including: advanced vehicles, advanced armament concepts, situation understanding and command and control, strategic and intra-theater lift, and prompt precision fires from all sources. Each of these technology areas is discussed in this report, with further detail in the annexes to Volume I and in Volume II.

Advanced Vehicles

Two new families of land combat vehicles are needed. The Rapid Response Liaison and Combat Support and the Light Infantry Response forces need a family of vehicles with high payload-to-weight ratio, advanced space frame architectures, enhanced energy efficiency, high reliability, and compactness for strategic transit. Command and control, mobile weapons systems, and combat support vehicles and their combat loads need to be transported by utility helicopters like the current UH-60 fleet or its follow on. All assets, including logistic transports or their loads, should be within the lift limitations of the current heavy lift helicopters (CH-47 and CH-53) or the MCV-22.

The Light Mechanized Strike force needs a family of combat vehicles with a high protection-to-weight ratio, enhanced energy efficiency, high reliability, rapid ground mobility, and compactness for strategic transit. This family of vehicles should provide a high degree of mobility and protected ground fighting power tailored to exploit the special conditions

encountered early in counter aggression campaigns or those encountered later in the fluid, non-linear engagements in the enemy's rear areas.

Both the LIR and LMS require a light advanced aerial attack and reconnaissance platform. It is not clear at this time if this platform should be a conventional rotary wing aircraft – a helicopter – or a tilt rotor. In either case, the aircraft avionics suite should include advanced target acquisition sensors such as signals intelligence, advanced infrared imaging, and synthetic aperture radar (SAR) with ground moving target indication (GMTI); munitions such as LOCAAS and advanced Hellfire; and advanced aircraft survivability equipment such as advanced radar warning receivers and jammers, missile launch detection and tracking sensors, and an active missile sensor defeat system such as a laser to counter infrared missile seekers. This aerial attack and reconnaissance platform is networked to the land combat vehicles and tactical aircraft with a two-way digital data link such as the Joint Tactical Information Distribution System (JTIDS).

Advanced Armament Concepts

The Light Infantry Response and Light Mechanized Strike forces would be capable of calling remote fires from systems such as the Submarine Precision Attack System described later in this chapter. Organic to both types of forces would be a follow-on to the high mobility artillery rocket system (HIMARS) sized for emplacement by heavy lift helicopters (CH-47, CH-53, and their follow-on) firing Moving and Stationary Target Acquisition and Recognition (MSTARS)-type munitions at greater than 60 kilometer ranges and two configurations of "rockets in the box," discussed in Volume II.

Assured Knowledge Superiority

Assured knowledge superiority is a key enabler for the rapidly deployable early entry force. The knowledge superiority system supporting these early entry forces has to be highly reliable and credible. The most effective way to achieve these objectives is through a multi-tiered architecture, where each layer has specific responsibilities, but also has the capability to provide back-up functionality for adjacent layers. The layered Integrated Information Infrastructure (III), described in Chapter 4, is the command, control and information dissemination concept to manage and direct these forces and is the core enabler to achieving knowledge superiority.

Prompt, Precision Fires

The most elementary limit to early and continuous combat effectiveness is the speed with which offensive systems can bring combat power to bear over intercontinental distances. Especially in higher-end contingencies, there will be targets identified for attack in the opening hours of the war, such as national-level command and control, telecommunications nodes, air defense operations centers, and weapons storage sites, particularly for weapons of mass destruction. Attacks against such targets need to be precise and minimize collateral damage and civilian casualties. These constraints, along with the desire to dominate future combat operations from the first hours, lead to a requirement for the kind of prompt, long-range, precision fires called for under Joint Vision 2010's concept of precision engagement. Several long-range precision strike systems are discussed in the sections to follow.

RECOMMENDATION

The DSB task force recommends that the Department define and establish, through experimentation, joint early entry combat force packages and develop the enabling technologies necessary for their effective operation. These air, ground, and naval forces need to be agile, lethal, and survivable and able to operate in any contingency.

In addition, the task force supports the development of a family of lightweight, energy-efficient vehicles to include a lightweight armored vehicle and a general purpose wheeled vehicle that is less than half the weight and cube of the HMMWV.

LONG-RANGE AIRCRAFT PRECISION ATTACK SYSTEM

The United States currently has programmed 208 long-range bomber aircraft in its inventory – 93 B-1s, 21 B-2s (not yet all delivered), and 94 B-52s. In the past, long-range bombers have been used as "trucks" to ferry and deliver large numbers of unguided gravity bombs. While these missions have contributed to US air power successes, including psychological effects on the morale and fighting abilities of enemy forces, effective lethality levels against targets could only be achieved by dropping large numbers of bombs in multiple sorties from high altitudes.

This proposed initiative for a long-range aircraft precision attack system would improve the effectiveness, operations, and sustainment of the current fleet of long-range bombers. Upgrading the weapon carriage, communications, maintainability, and survivability of the bomber force would enable the bombers to deliver large numbers of precision weapons against both fixed and mobile targets.

The ability to strike from global ranges reduces some of the constraints associated with potential theater basing restrictions and reduces the vulnerability of the force to attack. Delivering conventional munitions, the long-range bombers have an increasingly important role in contingency operations ranging from a show of force to engagement in a major theater war. Some of the important force implications of this capability are:

- rapid initial response of the long-range bomber attack force;
- reduced numbers of forward-based US forces;
- the ability to operate from bases beyond the range of many enemy strike capabilities;
- the large payload capacity and the emerging ability to deliver precision munitions to include long-range, stand-off precision munitions;
- the ability, with variable levels of targeting support, to hold both fixed and mobile targets at risk anywhere in a theater of operations;
- the endurance for on-orbit, on-call mission; and
- the ability to reinforce forward-presence enabling forces.

ENABLING TECHNOLOGIES

Precision Weapons

Precision-guided munitions extend the capabilities of all bombers and should dramatically enhance and strengthen their role. With the addition of precision-guided munitions, this bomber force can now attack multiple, discrete targets, both stationary and mobile, with high effectiveness. Key weapons that can or should be able to be carried by the bombers are described in more detail later in this chapter.

Adaptive Mission Planning and Weapon Accuracy

New computerized mission planning aids facilitate the ability to plan a strike mission that results in minimum risk to the aircraft while providing an optimum delivery approach profile for precision weapons. In the recent past, many hours and, in some cases, days were required to plan an attack mission against multiple enemy targets. Advanced planning systems will reduce the planning time to near real time, with in-the-cockpit weapon allocation in response to changing target opportunities. If bombers or standoff missiles are equipped with global, secure data link communications, the adaptive planning systems can update the aircraft and missile payloads while in flight. Advanced planning aids can also incorporate the effects of enemy radar detection and route aircraft around or through defenses that will minimize the number of possible detections and encounters.

Advanced Seeker Technologies

Crucial to achieving high weapons lethality is high accuracy, which in turn depends on weapon guidance and seeker technologies. Use of GPS has revolutionized weapon applications and can put a weapon in close proximity to its target even in poor weather. Differential GPS (DGPS) can improve delivery to sub-meter accuracy. For precise delivery, which can be defined as less than 1 meter circular error probable (CEP) accuracy, advanced seeker technologies offer an affordable way to equip a large array of launch and leave weapons with a precision attack capability. Advanced seekers using multiple sensors such as millimeter wave, lasers, infrared imaging arrays, digital scene matching, and acoustics can provide high precision and help discriminate real targets from decoys using on-board automatic target recognition (ATR) processing. For example, LOCAAS has the capability to discriminate armor targets from "trucks," employing a low cost laser radar seeker and on-board ATR.

Assured GPS and Command, Control and Communications (C^3)

One of the difficult challenges associated with the long-range precision attack force is assured GPS and C^3. Relatively low-power jammers can degrade the accuracy of current generation guided GPS weapons. With increasing dependence on GPS for accurate platform navigation and weapon delivery, the United States needs to ensure reception of GPS signals in the presence of jamming or deception.[10] This can be achieved by using adaptive nulling antennas, by increasing satellite transmit power levels, and by incorporating more jam-resistant digital coding techniques in the receivers. Enemy GPS jammer sites can also be attacked directly

10 Annex E, in this volume, offers a detailed discussion of survivability of the Global Positioning System.

during defense suppression operations if they can be located. One goal for protecting GPS is to require enemy jammers to operate at tens of kilowatt power levels making them more costly, physically larger, require large prime power sources, and thus easier to locate and destroy.

To command and control the precision attack force, effective global information systems need to be in place and sustained throughout the conflict. Assured knowledge superiority is critical for force employment, targeting, adaptive mission planning, real-time avoidance of enemy defenses, sensor management, and weapons control through data links. Adversary attempts to jam or disrupt US information systems and attack vulnerable C^3 nodes can be expected. Advanced information technologies covering distributed networks, intelligent terminals, adaptive routing, anti-jam communications, and other means should be incorporated into US systems to ensure a robust and survivable command and control capability across the spectrum of conflict. The discussion of the Integrated Information Infrastructure in Chapter 4 and Annex K addresses these operational and technical challenges.

MAJOR UNCERTAINTIES AND RISKS

The major uncertainties and risks associated with developing a long-range aircraft precision attack system are in the targeting and precision weapons systems, not the aircraft platform. Potential enemies have learned lessons from Desert Storm and are burying key facilities underground, hiding them within urban areas where collateral damage risks are high, and developing and deploying sophisticated decoys. Other survivability measures include rapid mobility to defeat mission planning systems – especially of surface-to-surface missiles and air defense systems (surface-to-air missiles and anti-aircraft artillery) – and hiding targets in foliage where current sensors have difficulty penetrating, especially at long range.

There is also a question of the availability of needed off-board sensors. For example, a Discoverer II-like space-based near-continuous coverage SAR/GMTI would be a critical all-weather, day/night targeting system to provide ingressing bombers with real-time target updates. The large number of precision weapons that can be carried by the bomber fleet will put significant demands on targeting and Command, Control, Communications, and Computers and Intelligence, Surveillance, and Reconnaissance (C^4ISR). Not only must the large number of targets be processed, but the nature of the various targets will require different and new sensor capabilities such as hyperspectral imagery to defeat camouflage and a low-frequency radar to penetrate foliage and image and track targets.

The Air Combat Command shows planned and funded bomber upgrade costs to be about $1.0 – 1.8 billion for the B-1, $650 million for the B-2, and $150 million for the B-52. This does not include other upgrades such as a relative targeting system or a Link-16 capability for the B-1, improved low observable performance for the B-2, or integrating new weapons such as small precision bombs (SPB) and LOCAAS on bombers.

RECOMMENDATION

The DSB Summer Study task force endorses the findings and recommendations of the Long Range Air Power Panel and recommends that the Air Force continue its program of

upgrading and improving the current bomber force to enable it to operate as a precision attack system. Improvements should include the following:

- improve B-2 stealth performance and low-observables-related maintainability;
- upgrade the precision munitions payload capability of all the bombers;
- increase the responsiveness and capabilities of the on-board mission planning system and command, control, and intelligence;
- improve real-time mission planning for the bomber force to exploit the capability to attack multiple, high-leverage targets per sortie;
- install Milstar II terminals in the bomber force;
- improve the bombers' offensive radar system to permit high delivery accuracy for the B-1 and B-52; and
- increase bomber sortie rates to leverage the full potential of the current bomber force to deliver dominant early and continuous combat effectiveness.

Estimated total cost of these upgrades is about $2 billion over the future years defense plan.

SUBMARINE PRECISION ATTACK SYSTEM

The proposed submarine precision attack system, the Trident SSGN, would be covert and able to carry a large number and variety of missile systems. In the crucial early hours of a campaign, against high-priority targets that are critical for an integrated defense by the enemy, covertness allows "out-of-the-blue" strikes from unexpected directions. Such strikes maximize the chance that the enemy is in a lower state of alert, increasing the effectiveness of the strike and the potential for success. If the undersea missile launcher has been positioned within range, the uncertainty involved in a strike is limited to missile performance against the targets and the effectiveness of missile defense against an attack with no warning.

It is expected that, within the next few years, implementation of the Strategic Arms Reduction Treaty (START) will result in removing four OHIO Class SSBNs (Trident) from the US strategic arsenal. These four Trident submarines, with considerable service life remaining, could be converted to non-strategic, conventional weapons, tactical mission platforms, termed SSGNs. The proposed program of converting four Tridents would provide hundreds of missiles on-line in six years. In a conflict, the Trident SSGN would provide prompt strike response with vertical launch system (VLS) capable weapons (Tomahawk, ATACM, Joint Air-to-Surface Standoff Missile (JASSM), and Standard Missile variants) and with other future development payloads such as a conventional sea-launched ballistic missile (SLBM), air defense missiles, and missile defense interceptors.

The proposed conversion program has low technical risk because these capable, proven ships are available, the weapons and fire control systems are available, and ship modifications will be minimal. Figure 11 shows details of the ship configuration.

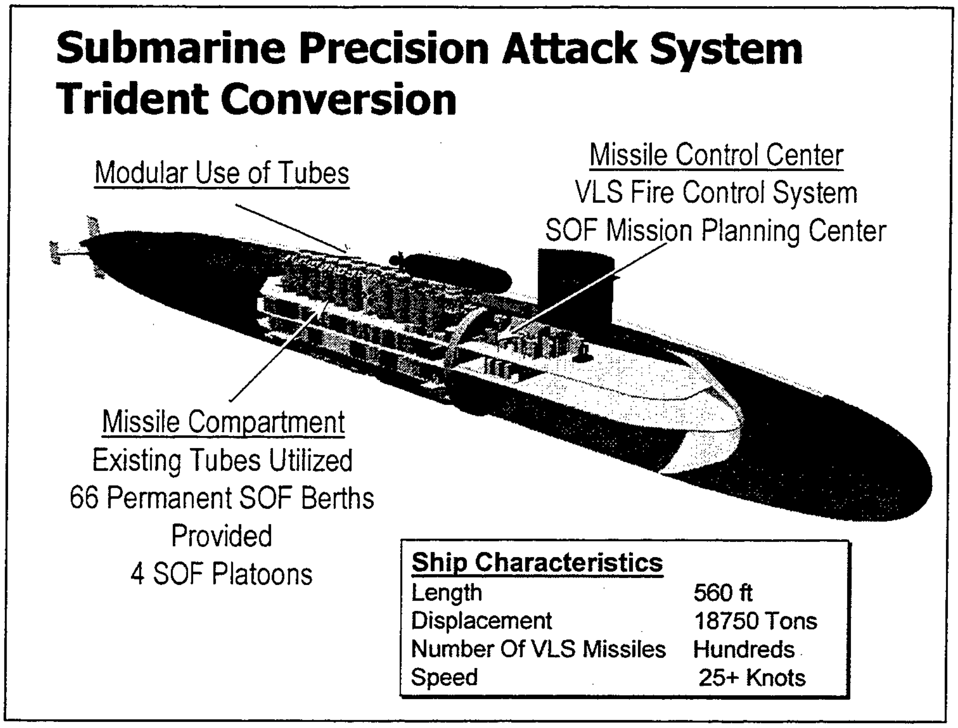

Figure 11. Trident Conversion

CONCEPT OF OPERATIONS

With four Trident SSGNs, two ships could be forward deployed at all times in a conventional deterrent role. The autonomy and inherent stealth of Trident submarines would introduce a significant unknown into the calculus of any potential adversary. Although no US surface forces might be in a given area, an adversary could not discount the fact that there could be a Trident SSGN within striking range.

The Trident SSGN would provide the theater Commander-in-Chief (CINC) with a covert precision strike and special forces platform that can be positioned in a non-provocative manner. The proposed conversion would leverage an existing platform to provide up to hundreds of missiles and dual dry deck shelters for delivery of over 100 special operations forces (SOF) (4 full platoons). In order to fully integrate with the joint task force and provide full targeting and communications connectivity, a SSN communications suite would be backfitted into the SSGNs. This wideband, high data rate communications system will be compliant with the Joint Chiefs of Staff Joint Fires Architecture and can utilize ELF, VHF, UHF, SHF, EHF and GBS joint communications circuits.

The SSGN platform could make a significant impact early, since it can be on station, ready to respond, without the need to first establish sea or air superiority. The submarine could operate securely from most threats that pose a hazard to US forces operating close to enemy shores; thus it can be present before hostilities break out. The SSGN can also provide intelligence, reconnaissance, and warning. It can be used to map aspects of the battlespace using the planned advanced rapid commercial off-the-shelf high-frequency sonar suite capable of providing precision maps of the undersea battlespace including detecting mines. Recent studies and war games have shown that early firepower can play a significant role in halting invasion forces. A

swift attack may serve to stop escalation. In some operational concepts, sea and air superiority are not assured early and a covert submarine platform may be the preferred source of early fire power.

There is a growing concern about the development of layered defense systems that create an in-depth anti-access barrier to naval operations in littoral seas and out to ranges of 1000 to 2000 miles from their shores. In such cases, the Trident offers a high probability of surveillance penetration.

The Trident ship platform has operated reliably since it became operational in 1981. The Trident SSGN will benefit from proven operational concepts and an existing, robust infrastructure. Refit facilities at Kings Bay, Georgia, and Bangor, Washington, can continue to maintain these ships at a high state of readiness. The effectiveness of the repair cycles on the Tridents has been borne out by the fact that previously planned shipyard overhauls have been replaced by routine homeport refit periods. After conversion and refueling, these ships will have 20 years of service life remaining.

CHALLENGES

START Implications

START I. Based on START I counting rules, a submarine missile tube counts against START warhead limits until the tube is physically cut out of the submarine. Under START I, four Trident submarines would count for 576 warheads (4 submarines x 24 missiles per submarine x 6 warheads per missile). However, because the START I warhead levels are significantly greater than current US inventory, counting these "phantom warheads" on four converted Trident submarines still maintains US warhead levels under START I limits.

The FY 1998 Defense Authorization Act limits the use of funds for retiring, dismantling, or preparing to retire or dismantle below the limit of 18 Trident ballistic submarines unless a START II Treaty enters into force during Fiscal Year 1998. START I Treaty language provides latitude to move forward with a Trident SSGN conversion program. After FY 2000, the Secretary of Defense may determine alternative force structures as appropriate.

START II. START II was signed in 1993, ratified by the Senate in 1994, but still has not been ratified by the Russian Duma. Russian ratification of START II is uncertain. START II requires SLBM delivered warheads be reduced to 1750 by December 31, 2003, and to 1750 accountable warheads by December 31, 2007. Subtracting the 384 phantom warheads that would be attributed to four converted Tridents (SLBMs would be attributed 4 warheads per missile under START II), would leave the United States with 1344 actual SLBM warheads allowed after December 31, 2007.

According to the FY 1998 Defense Authorization Act, if the Russians ratify START II, the Secretary of Defense may waive the 18 SSBN limit as necessary to implement the Treaty.

Trident SSGN Conversion Costs

The Trident conversion program calls for decommissioning the first of four Trident C-4 SSBNs beginning in 2002. If the SSGN conversion program is funded, a two-year lead time is

needed in order to prepare for the conversion. Hence, for SSGN conversion and refueling to begin in 2002, the program needs to be funded by FY 2000.

Refueling and conversion costs for a four ship SSGN program is $1.86B, detailed in Table 1 below, in addition to $155M annual operations and support costs. The Navy currently has $353M programmed to inactivate these ships in Fiscal Years 2002 and 2003. This money could be used to reduce the unprogrammed cost for a four-ship refueling and conversion program to $1.52B. Since part of this conversion includes major accommodations for SOF operational capabilities, the Commander-in-Chief of Special Operations Forces has agreed with the Navy to cost share in this conversion, contributing $80M per ship for the SSGN configuration.[11]

Table 1. Trident Conversion Costs

First Ship Costs (Non-Recurring)	
Ship Design	$112M
GFE Design	32M
Missile Certification	17M
Total	*$161M*
Per Ship Costs (Conversion)	
Refueling Overhaul	$269M
Ship Conversion	129M
Government Furnished Equipment Hardware	25M
Missile Certification	3M
Total	*$426M*
Operational Costs Per Ship	
MPN for 2 crew (14 Officers and 127 Enlisted)	$13.5M
OMN Depot Level Maintenance	1.9M
OMN Intermediate Level Maintenance	13.5M
OPTAR	1.2M
Weapons OMN	5.0M
NAVSEA 08 Annual Fuel Charge	.1M
Ship Operation Support and Training	2.8M
Platform Support Equipment, NAVSEA OPN	.7M
Total	*$38.7M*

Trident SSGN presents a unique near-term opportunity to provide a high-capacity precision strike capability in a low risk and affordable program. The Defense Science Board recommends that the Department of Defense convert four Trident submarines to the SSGN configuration.

[11] The level of funds coming from the Commander-in-Chief of Special Operations Forces is still under negotiation. This was the latest information available to the DSB task force.

SUBORBITAL SPACE OPERATIONS VEHICLE

The SOV would provide aircraft-like access to Mach 17+ energy states for intercontinental projection of lethal or non-lethal power using the Common Aero Vehicle and miniature munitions technology, as depicted in Figure 12. Currently, the Air Force has Boeing and Lockheed Martin under contract to study both the SOV and the CAV concepts. Boeing has also developed, under an Air Force contract, the X-40A technology demonstrator of the Space Maneuver Vehicle which was successfully air-dropped in a first flight test on August 11, 1998.[12]

The concept of operations, signed by the Commander, Air Force Space Command on February 9, 1998, envisions the SOV executing a suborbital (or "pop-up") flight trajectory to release payloads such as CAVs during exoatmospheric flight. The SOV could launch and recover from dispersed locations, most likely in the continental United States, reducing the probability of launch detection and obviating regional CONUS access challenges. The payload would continue on a suborbital flight path, using its lifting body shape for range extension within the atmosphere. The CAV would stay above national airspace until over the target nation or area. Following CAV release, the SOV would return to Earth, about 2,000 nm from its launch location, and land vertically or horizontally, depending on the final system configuration. The vertical profile allows short or no-runway operations and significantly reduces the re-fuel and re-arm time before the next mission.

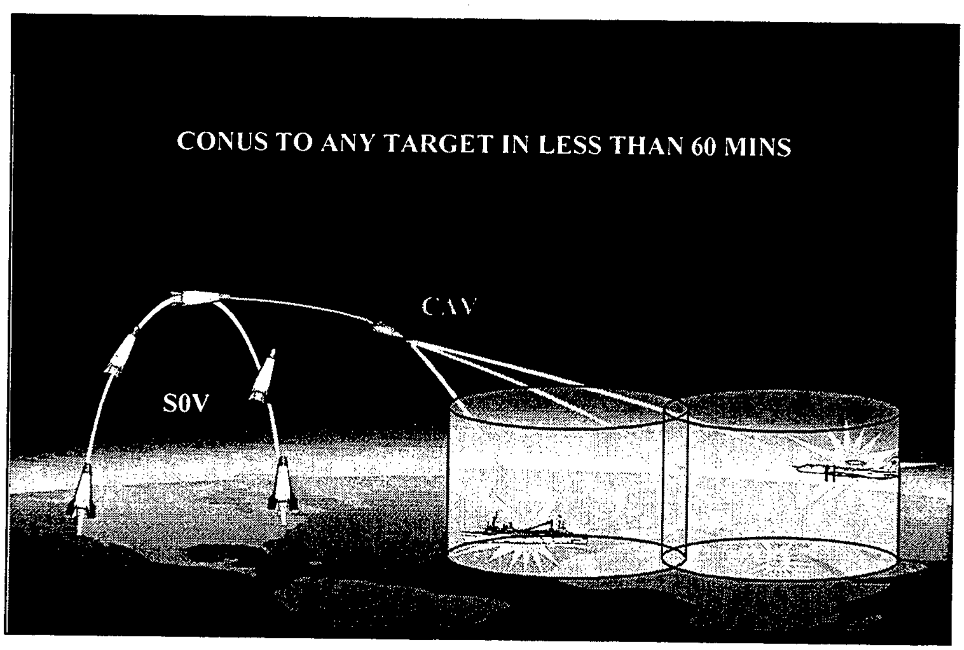

Figure 12. Suborbital Space Operations Vehicle and Common Aero Vehicle

The development of the Space Operations Vehicle could be a close derivative of the NASA X-33 Single-Stage-to-Orbit (SSTO) Reusable Launch Vehicle program, thus reducing

[12] The X-40A is a 90 percent scale, reusable, experimental vehicle weighing about 2,600 pounds and is 22 feet in length with a wing span of 12 feet. It utilizes a GPS navigation system to perform autonomous approach and landing.

development cost and risk. If the X-33 demonstration in 1999 is successful, the commercial full-scale variant of the X-33, called VentureStar™, is expected to achieve operational status in 2004. While NASA is funding the $1B X-33 SSTO technology demonstrator, the full-scale VentureStar™ would be commercially funded, and intended to deploy commercial satellites and accomplish resupply of the International Space Station.

The suborbital vehicle could also deliver payloads such as a Space Maneuver Vehicle (SMV), shown in Figure 13.[13] Depending on loadout, the SMV could conduct space asset protection, satellite logistic resupply, ballistic missile defense, space-to-space, space-to-air, or space-to-ground missions (with CAV). SMVs could boost themselves into orbit using their on-board propulsion systems. Sensor packages could then be recovered after "once around" missions for near-real-time reconnaissance. The SMV would overfly any location on Earth in less than 60 minutes and collect high-resolution imagery or other intelligence.

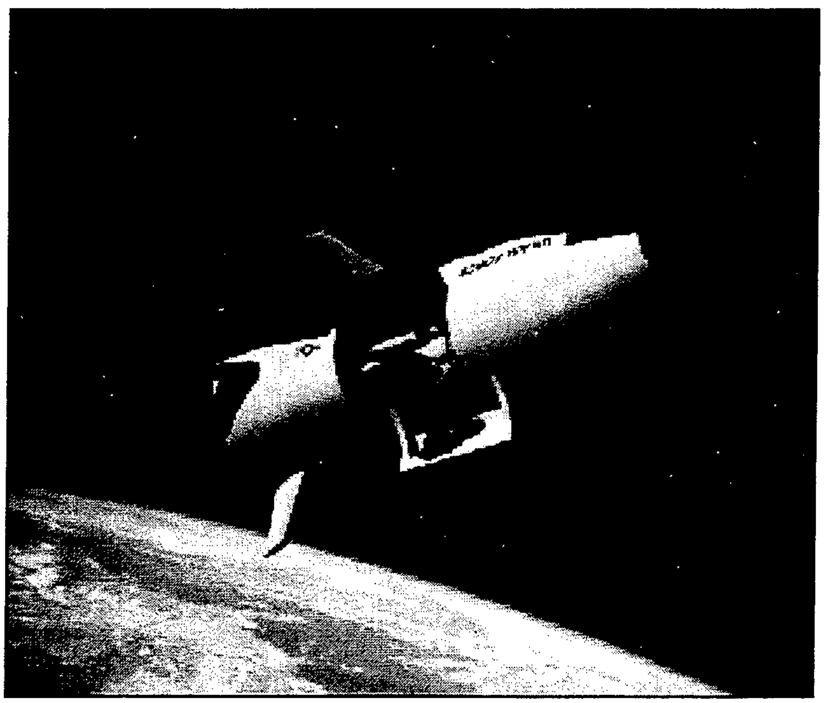

Figure 13. Space Maneuver Vehicle

The SOV does not require a new technology start and integrates with presently programmed programs. There is currently no funded program for the Space Operations Vehicle, Space Maneuver Vehicle or Common Aero Vehicle to deliver capabilities at a level sufficient to support Joint Vision 2010.

There is some support in Congress. From the National Defense Authorization Act of 1999, as offered by the House National Security Committee: "...The committee notes that US military forces are increasingly reliant on space-based capabilities and the Air Force has identified

[13] Annex H contains additional material on the Space Maneuver Vehicle and Common Aero Vehicle.

requirements that are best met by a military space plane and an associated family of vehicles. The committee understands that any military space plane effort should focus on military unique requirements and leverage NASA investment in the reusable launch vehicle program. The unique requirements are reflected in development efforts for a Space Maneuver Vehicle (SMV) that would provide all-orbit access and extended on-orbit dwell time, a low-cost expendable upper stage to deploy payloads to all orbits, and a common aero vehicle (CAV) that would serve as a maneuvering reentry vehicle capable of delivering various paylaods anywhere on earth within an hour of launch. The committee believes that a military space plane and its related elements have the potential to contribute significantly to US military capability."

The Defense Science Board recommends that the Air Force proceed with development of a Space Operations Vehicle and Common Aero Vehicle for flight demonstrations of the SMV and CAV payload. Every effort should be made to develop the SOV as a military derivative of the NASA Reusable Launch Vehicle program to reduce risk and cost.

ADVANCED MUNITIONS

In future military operations, commanders will want strikes from remote systems to support theater objectives to include distributed ground operations. The objective is to develop a suite of systems to achieve high effectiveness from the first round of indirect fire. Key weapons in the current inventory of conventional munitions, or in development, include:

- ***BAT.*** Brilliant Anti-Armor Submunition is an unpowered, aerodynamically stable, self-guided submunition developed by the Army. After being dispersed, the submunition autonomously seeks out and destroys moving and stationary targets; the BAT preplanned product improvement offers an enhanced acquisition capability using improved infrared, millimeter-wave, and acoustic sensors; an improved warhead; and more robust capability in adverse weather.
- ***GBU-37.*** Formerly known as GATS/GAM, named after the B-2 bomber's GPS-Aided Targeting System (GATS) and the GPS-Aided Munition (GAM). Retrofits the BLU-113 warhead (4,444 lb Desert Storm Bunker Buster) with a GPS-aided inertial guidance kit and nose strakes for improved accuracy and adverse weather capability against a wide range of hardened and/or deeply buried targets requiring a robust penetrating munition with substantial high explosive volume (647 lb). Kits were developed/refined to handle unique control problems associated with BLU-113 weight and length (153 in.) Currently integrated for B-2 carriage only.
- ***JASSM.*** The Joint Air-to-Surface Standoff Missile is a joint Air Force and Navy program to provide a survivable, accurate (<3m CEP), area standoff (>100nm) capability for attack of fixed, high value, defended, soft and hardened point targets.
- ***JDAM.*** The GBU-31/32 Joint Direct Attack Munition retrofits gravity unitary warhead bombs with a GPS-aided inertial guidance kit for improved accuracy and adverse weather capability against a wide range of fixed, stationary, and in some cases, mobile targets. The kits are being developed for both the 2,000 pound class MK-84/BLU-109 (GBU-31) and the 1,000 pound class MK-83 (GBU-32) bombs.

- ***JSOW.*** The Joint Standoff Weapon is a joint Navy and Air Force unpowered, standoff (>15nm) glide bomb. Both unitary and cluster variants of the missile are planned although the Navy recently announced that funding for the unitary variant was withdrawn.

- ***LOCAAS.*** The Low Cost Autonomous Attack System is a small, lightweight submunition with a terminal seeker and multi-mode warhead designed to be used against ground mobile targets. LOCAAS has not yet entered the Engineering and Manufacturing Development (EMD) phase, but has such high potential that the Department should ensure continued support for this system. Material in Volume II describes LOCAAS in more detail.

- ***SPB***. The Small Precision Bomb system is to provide small warhead (250 pound class) bombs with an inertial navigation system and differential GPS guidance kit to yield an accurate, adverse weather capability to attack fixed or stationary targets. Due to its small size, significant numbers of bombs could be carried by stealthy fighter aircraft such as the F-22 and Joint Strike Fighter and as many as 300 bombs by long-range heavy bombers – the B-1s, B-2s, and B-52s. Volume II has an expanded discussion of SPBs.

- ***Tactical Tomahawk.*** Tomahawk is a precision strike, surface-to-surface missile launched from ships or submarines against high value, heavily defended targets. The Tactical Tomahawk will be a more versatile version of the system, addressing the Navy's requirement for a missile that can rapidly respond to "call-for-fire" against time-sensitive targets. This upgrade will add the ability to retarget a missile in flight, loiter over the battlefield for more than two hours waiting tasking, and provide target assessment photos through the use of a battle damage imagery camera.

- ***WCMD***. The Wind Corrected Munitions Dispenser provides an inertial navigation system guidance and control tail kit to improve the accuracy and effectiveness of Tactical Munition Dispenser cluster weapons (CBU-87/89/97).

In addition to the current and evolving inventory of conventional munitions for aircraft and missile delivery, there are new precision weapons needed to take advantage of advances in guidance, seeker, and warhead technologies. Figure 14 highlights new capabilities for remote fires that can be employed under the joint early entry force concept: real-time capability to manage ensembles of both sensor and weapon systems, in-flight weapon redirection, loitering weapons to deal with time-urgent and mobile targets, ability to gain knowledge superiority, and integrated battle damage assessment.

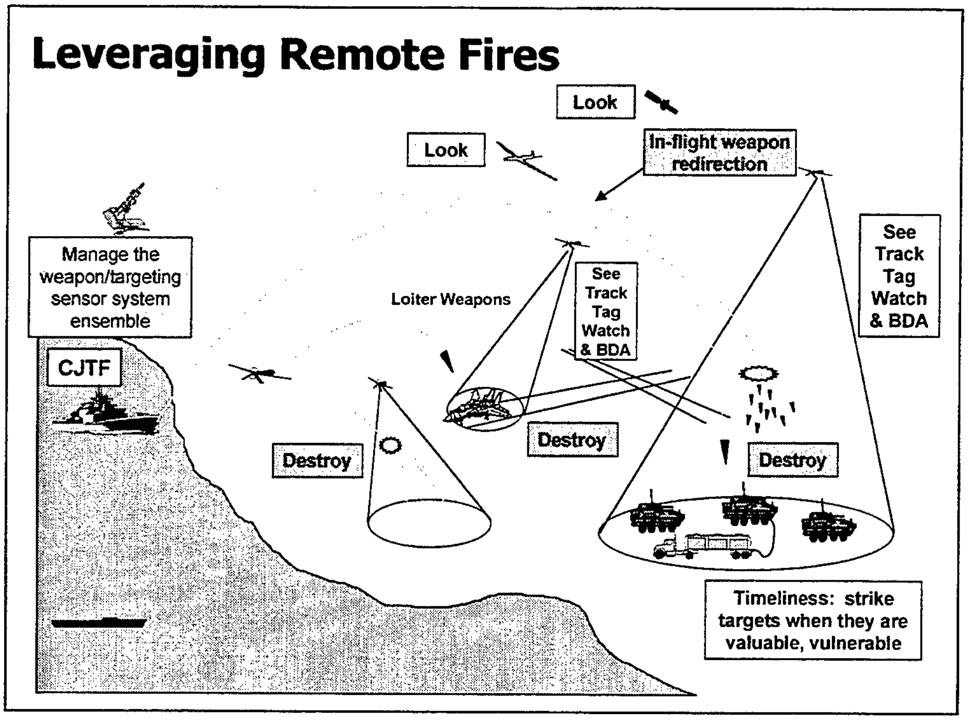

Figure 14. Leveraging Remote Fires

As previously discussed, it will be possible in the 21st century to develop and globally deploy a military DGPS capability to any conflict area. The DGPS will contain anti-jam and other unique features to provide high assurance of signal availability and accuracy. In addition, the United States will have collected and updated global digital terrain elevation data (DTED) to 1-3 meter accuracy. The combination of real-time DGPS, digital terrain data, and highly accurate, space-based imagery (electro-optical/infrared/SAR) with ground moving target tracking capability, would make it possible to register fixed and moving targets on the battlefield to submeter accuracy. Rapid registration updates would also be possible using the dynamic collection capability of space-based imaging and tracking systems augmented perhaps with high altitude, long-endurance (HAE), unmanned aerial vehicle (UAV)-based sensor systems.

This registration and DGPS now make it possible to consider new families of high precision munitions such as the DGPS-guided SPB. As target location error is driven to submeter accuracy, even smaller and lighter but lethal, high-precision weapons could be possible.

Seeker and automatic target recognition technology is rapidly evolving to affordable levels such that weapons can be cost-effectively employed to selectively attack high-leverage, high-cost (to the enemy) tactical targets such as armor. Laser radar and millimeter wave seekers are technically maturing and are at affordable costs to yield a rich menu of new options for launch and leave, high-precision munitions for air or missile delivery.

Two other features are needed in future munitions. One is the ability to be launched, loiter over or near a battlefield, and then attack a tactical target, such as a missile transporter emerging from an underground facility. Tactical Tomahawk will loiter for a few hours and LOCAAS can loiter for about thirty minutes. DoD needs more loiter weapon options, especially in support of dispersed US forces, to be responsive to time-urgent calls for indirect fires.

Another feature needed on future munitions, and especially longer-range missile systems, is the ability to receive and process new targeting data and then adjust the trajectory in real time. This in-flight guidance update enables long-range ballistic missiles to be used to engage moving tactical targets. With perhaps ten to twenty minute flight times, the missile would need target updates in flight to put moving targets within the missile payload engagement footprint. Tactical Tomahawk will have this feature. The naval version of Tactical Missile System (TACMS) needs this feature, as would other proposed ballistic missiles for land attack, deployed on surface ships or Trident submarines.

The task force recommends that the Department, with the Under Secretary of Defense for Acquisition and Technology as the lead, field a family of advanced munitions in needed numbers. This family of munitions should include both current development programs as well as the development of more advanced munitions.

SUMMARY

In summary, key enablers for a joint early entry strike capability are shown in the chart below. These enablers will lead to a force that is more potent than today's light forces and more agile and deployable than today's heavy forces. Combining air, naval, and ground forces – such as those described in this chapter – and leveraging joint fires and information operations capabilities, the joint early entry strike force will give the United States the needed response capability to meet the demands of the range of future warfare contingencies.

- Superbly Qualified Commanders
- Shared Battlespace Awareness
- Remote Precision Fires
- Assured Connectivity to Fires
- Agile On-Time Logistics
- Lightweight, Energy Efficient Vehicles
- Rapidly Deployable Anti-Armor

More Potent than Light Forces

More Agile and Deployable than Heavy Forces

CHAPTER 4.

Primary Operational Challenges

Perhaps the most pervasive operational challenge enabling early and continuous combat effectiveness is knowledge superiority.

CHAPTER 4.

Primary Operational Challenges

This chapter describes four operational challenges that enable early and continuous combat effectiveness: assured knowledge superiority, responsive global targeting, flexible and survivable inter- and intra-theater mobility, and exploiting the littoral battlespace.

Assured Knowledge Superiority

Perhaps the most pervasive operational challenge enabling early and continuous combat effectiveness is knowledge superiority. With nearly two thousand commercial telecommunications satellites on orbit by 2010, along with widespread deployment of fiber optic terrestrial and trans-oceanic cables, the globe is rapidly becoming "wired." Today, many nations are developing commercial, high-resolution, space-based, electro-optical, infrared, and radar imaging systems. These developments, coupled with the ready availability to any nation, group, or individual of the latest technologies in network and computer hardware and software, will make it difficult for the United States to maintain overwhelming "information superiority."

For these reasons, this DSB task force suggests that the Department of Defense aim for "knowledge and decision superiority," even in those circumstances when information superiority is not assured. DoD can do this by bringing the judgement of superbly trained military personnel to bear on exploiting America's superior capabilities to correlate, manipulate, and present information created from raw data. The enabling capabilities to develop knowledge superiority are arrayed across the lower part of Figure 15.[14] Across the top of the chart, from left to right, is the expected evolution over time to achieve knowledge superiority as noted in the box on the top right.

This section covers four key enablers, shown in Figure 15: command and control, sensor systems, the Integrated Information Infrastructure, and information operations.

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[14] DoD has developed a methodology to evaluate the utility and value of C^4ISR systems. The Assistant Secretary of Defense for Command, Control, Communications and Intelligence (ASD(C3I)), in support of the Quadrennial Defense Review, conducted a C^4ISR Mission Assessment (CMA) examining all aspects of C^4ISR including space, airborne, and surface-based systems at national, theater, and tactical levels. The DSB task force believes that across-the-board reviews of this nature offer promise for accelerating the realization of Joint Vision 2010's imperative to achieve information superiority and for supporting other C^4ISR objectives. Accordingly, the task force recommends that DoD institutionalize the CMA process – jointly sponsored by the Joint Staff and ASD(C3I) – and conduct reviews biennially in time for consideration during the Department's planning and budgeting process. A standing CMA committee, supplemented by individuals from OSD, the Defense Agencies, and the military Services, would serve as the review team. The standing committee would also monitor implementation of CMA recommendations, refine assessment methodologies and perform other tasks as directed.

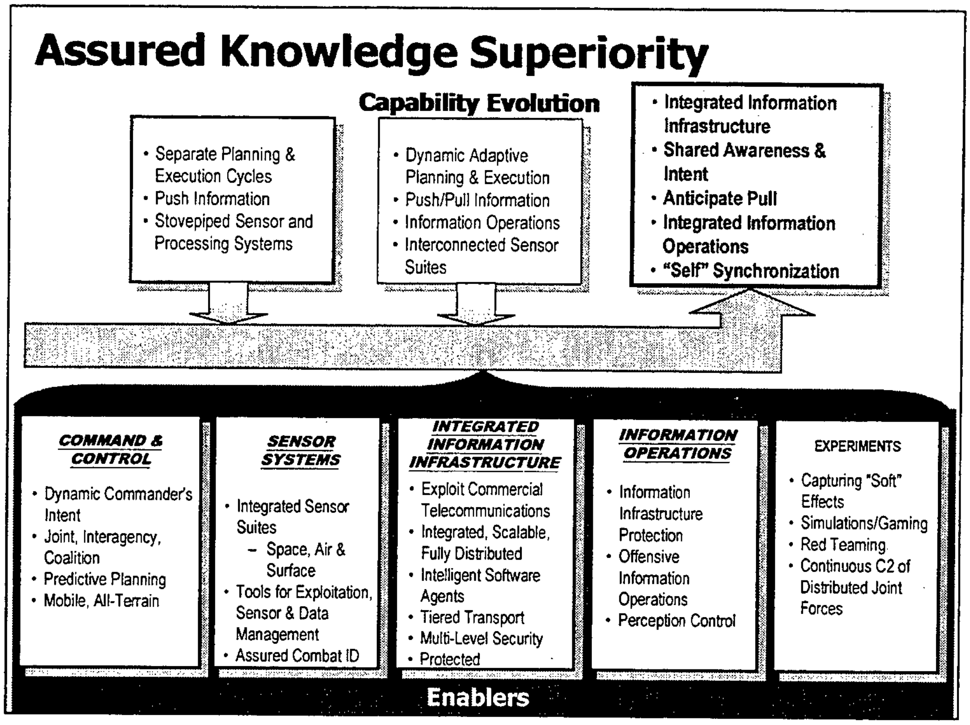

Figure 15. Assured Knowledge Superiority

COMMAND AND CONTROL

Command and control provides the direction for assigned and attached forces to accomplish a mission. It includes planning, directing, coordinating, and controlling forces and operations. The nature of warfare in the coming decades, and the technologies that will shape it, both demand and enable changes in command and control and its central function – decision making. These changes will be crucial to combat effectiveness. Future information systems should be designed to enable continuous and faster command decisions; coordination of dispersed units and operations; dispersal and mobility of headquarters for improved survivability and positioning; improved coordination with coalition partners and international and non-governmental organizations; and flexible and adaptive coordination and direction of forces and groups of interactive sensors.

Command and control is about decision making, and the United States is aggressively exploiting information technology to enhance this capability. As it relates to Joint Vision 2010, the objective of information superiority is *better and faster* decisions. Situational awareness is a necessary but not sole component of decision superiority. Data must be turned into relevant knowledge, which is combined with the judgement of commanders to achieve the decision superiority envisioned by and essential to Joint Vision 2010, as depicted in Figure 16. This process is supported by tools to enable and accelerate the planning and decision-making process.[15]

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[15] Annex I contains an interesting exposition on applying chaos and complexity theories to command and control and combat operations.

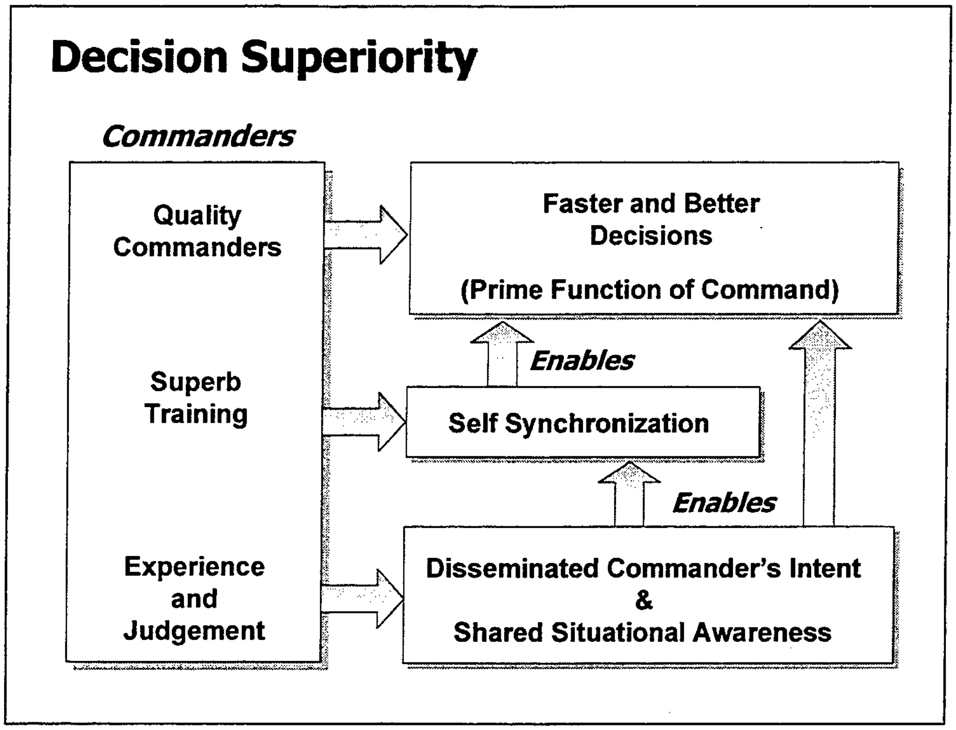

Figure 16. Decision Superiority

Commanders need to evaluate relevant knowledge within the context of the current and anticipated operational environment in order to make decisions about future actions and to convey those decisions in ways that facilitate their proper execution. The development of the right tools will allow the commander to focus better on those issues associated with the essence of command. As the United States develops more and better automated tools and trains people to use them, it will become more important to understand and educate to further the art of command.

Command and control needs to be addressed across the full spectrum of conflict from forward engagement designed to shape the environment, maintain alliances and ensure access; to stability and support operations including humanitarian assistance, disaster relief, counter terrorism, countering weapons of mass destruction, peace enforcement, peace making and peace keeping; to actual conflict. US command and control therefore needs to be global, operate in any terrain and on the move, and be sustained from early warning and crisis management through post conflict tasks.

The increase in operational tempo and the range of weapons available today demand that planning and execution be continuous rather than cyclical, time-phased, sequential actions. As stated in Joint Vision 2010, "Real-time information will likely drive parallel, not sequential, planning and real-time, not prearranged, decision making."

In the rapidly changing threat scenarios likely in the future, combat power in the first hours will require intelligence preparation of the battlefield, planning before the first strikes or insertions, and continuous update. Sustaining effectiveness beyond the first hours will require continuous combat, driven by continuous planning and decision-making that is based on

continuously refreshed information, and leading to improved understanding of the situation on the battlefield. The Summer Study task force believes that continuous combat operations should be an overarching objective of Joint Vision 2010. To support this objective, the Chairman of the Joint Chiefs of Staff should emphasize continuous planning and command decision making and evaluate all guidance and developments related to Joint Vision 2010 on this basis.

A network of communications and computers must be able to support mobile operations on the land, in the sea, and in the air. Command posts need to be small, agile, and mobile to survive and remain relevant. They also need to be redundant enough to support continuous operations and still accept some losses. The United States needs to conduct dispersed command and control operations while maintaining effectiveness.

As units reduce in size and disperse in the battlespace, sustaining cohesiveness and engendering increased capabilities in smaller forces will be challenges. As pointed out in Joint Vision 2010, US command and control approaches and capabilities need to "empower a degree of independent maneuver, planning, and coordination at lower echelons, which were normally exercised by more senior commanders in the past." If a current company-sized land force has the means to fight and control the space currently assigned to a battalion, how is that "company" provided the leadership to execute its mission? What are the qualifications for the commander? These questions of dispersed command and control capabilities and of smaller and more dispersed units – separating selected functions and relying on reach-back to link the elements – need to be answered through experimentation.

One of the difficult challenges is transforming data into knowledge. More sensors will provide more data from more locations. Access to more data may inhibit rather than support decision superiority unless this data are transformed into useable knowledge. Unique functional or organizational databases have limited utility. Relevant data need to be accessible throughout the area of operations. Information needs to be provided responsively to commanders through a combination of automatic feed (push) of information and aided query (pull) that accesses the right knowledge without requiring detailed human sorting.

Commanders continually operate in multiple time perspectives. Commanders use the information presented to develop a perception of the current situation. Concurrently, a commander projects the picture of the current situation into the future. Planning tools need to facilitate this process by providing current data and its related uncertainty, so that alternative courses of action can be assessed and future direction determined. Common tools for planning, rehearsal, directing, and execution monitoring are needed so that rehearsal and execution can be compatible. This will require flexible decision support tools with variable run times – faster to examine alternatives in the planning process, real time to monitor current operations, and slower than real time to support detailed rehearsals.

As operations are conducted with joint and combined forces, situational knowledge, understanding, direction, and execution need to be common across the force. Effectively integrating the capabilities of a joint and combined force demands common knowledge, common direction, and a reliable information infrastructure. Combined operations also require communication and coordination with a host of non-US and non-military organizations.

To enable the command and control capabilities needed for the future, information systems should be designed around six key information management concepts:

- Real-time sharing, across all command levels (vertically and horizontally), of a common dynamic view of the situation – battlespace understanding;
- Shared understanding, at all command levels, of commander's intent;
- Providing to commanders the information they need and can use – no more and no less – when they need it;
- Portraying, to the degree known, the uncertainties in the information provided to commanders;
- Providing a commander the flexibility to adapt the information system to changing needs; and
- Projecting the current situation into plausible future outcomes so courses of action can be assessed and future direction determined.

Implementing these concepts can effect the commander's transition from awareness, to knowledge, to *understanding* of the battlefield situation and its larger context. Common understanding of the current situation and of the commander's intent helps enable self-synchronization of units and operations. When combined with the experience and judgement of commanders, this leads to faster and better decision-making, which drives the impact of command on the battle's outcome, as depicted in Figure 16.

As previously stated, information superiority may be illusive. Yet, future force sizing and capabilities may be determined with an assumption of information superiority. The ability to guarantee sustained decision dominance can be uncertain and demands that information warfare – protecting US decision superiority and the ability to attack an opponent's decision processes – be an essential element of this concept. Further, since commercial capabilities are available to all, it is important that the United States be able to better integrate commercial products and be able to rapidly accept advances in capabilities to support command and control needs.

The panoply of information technologies can be applied to create information systems for the commander, which embody the six information management concepts listed earlier. Many of these technologies, such as increased bandwidth and computational speed, are relevant across the information architecture. Others are relevant to command decision making itself. Examples of the latter are automated decision aids, automated planning tools, and advanced display and visualization.

The task of creating command and control for the future battlefield is dominated by two interrelated issues: 1) what kind of command structures and processes are best suited to particular (possibly new) situations in future warfare, and 2) what information system architectures and technologies are best suited to support them? These matters are so complex – in part because command decision making is inseparable from the human capabilities and limitations of the commander – that resolving issues cannot be adequately supported by traditional analysis; experiments need to play the central role.

The task force supports the on-going process within DoD to adapt command and control doctrine and practice to new circumstances, based on the fundamental principles of command that have been validated by long experience. The program of recommended experiments is intended to complement and perhaps accelerate this process by emphasizing: risk-taking command and control concepts (for example, self-organization of dispersed operations);

exploring innovative C^2 concepts that could be leveraged to gain advantage or avoid risk; and exploring advanced information concepts, simulating potential capabilities that may be years away from realization.

This program of experiments would emphasize maintaining and enhancing human relationships among commanders – vertically and horizontally – in the absence of face-to-face interaction, as might increasingly be the case in dispersed operations or with distributed C^2 functions. Experiments addressing command and control would also emphasize the development of metrics that are related to the combination of speed and quality of decision-making, the ability to adapt to new circumstances, and survivability and robustness. The program should include simulations (especially commanders-in-the-loop simulations), command post exercises, field exercises, and combinations of all of these techniques. Experiments should explore command and control concepts across a wide range of command echelons and circumstances, but with emphasis on Joint Task Force command.

To support such a program of experiments, the Office of the Secretary of Defense (OSD) and the Joint Staff might consider constituting a standing group of retired military officers with experience in combat command, and civilian engineers and scientists with experience in relevant aspects of information technology. This group could review US Atlantic Command's (USACOM) ongoing work in developing C^2 concepts and supporting technologies, and help to shape an experimentation program in DoD. In addition, the Defense Advanced Research Projects Agency (DARPA) could develop a commanders-in-the-loop simulation that could be used to rapidly explore the broad systematics of alternative command and control structures and information architectures, as an aid in designing the program of experiments.

The DSB task force recommends that OSD, the Joint Staff and USACOM jointly plan and implement a comprehensive program of experiments to explore and develop, together and iteratively: 1) command and control concepts, structures and processes and 2) supporting information management concepts, architectures and technologies, to achieve situation understanding and decision-dominance on the future battlefield.

These command and control structures should enable:

- Immediate and continuous operations on the move,
- Dispersed forces and dispersed command and control,
- Shared real-time understanding of the situation and commander's intent, and
- Synthesizing data into knowledge, pushed to and pulled by the users.

SENSOR SYSTEMS

Comprehensive, real-time information about the battlespace and enemy actions, location, and intentions is an expected basis for future military operations. Comprehensive battlespace awareness relies on technical capabilities in sensors, sensor exploitation, and sensor management. This section assesses the adequacy of current technology for achieving comprehensive information, awareness, and knowledge about the battlespace – particularly, but

not exclusively on the ground – and recommends a variety of actions to consolidate and enlarge present-day technical capabilities.

In addition to an information infrastructure that is discussed in the following section, there are three top-level elements in a system-of-systems for comprehensive real-time battlespace awareness:

- Sensors that "see everything all the time." This means sensors that see objects or behaviors of interest whether stationary or moving, whether in the open or obscured by foliage, terrain, or urban structures, and regardless of how far-flung. It results in large amounts of data that are useful.
- Algorithms, processors, and visualization strategies for automatically reducing sensor information into manageable proportions.
- Scaleable sensor management techniques. "Seeing everything all the time" implies many sensors of different types that in turn implies a potential for redundancy and/or many ways for any particular information request to be satisfied. Sensor management needs to be responsive in real time to new intelligence or urgent changes in commanders' guidance.

Sensors. The current investment in remote sensing emphasizes signals intelligence, wide-area radar imaging with moving-target indication, and short-exposure electro-optic and infrared imaging of focused areas. Investment in local sensing emphasizes unattended ground sensors for seeing "around the next corner" or "into the next building," at best. These are crucial capabilities, but they leave important gaps with respect to Joint Vision 2010's "full spectrum" of conflict, such as the ability to penetrate weather, sense wide areas, penetrate foliage, and see into urban areas.

Sensor Exploitation. The task force is encouraged that ATR techniques are making their way into demonstration systems for exploiting wide-area high-frequency SAR imagery. However, ATR for other search sensors or modes is not quite as far along, and for some sensors remains in quite an early state. This includes visible and infrared imagery, where contrast look down is a problem, as well as hyperspectral imaging. Ongoing activities in ATR and sensor fusion need to keep pace with the increased sensor richness that Joint Vision 2010 implies: a capability – sensors, algorithms, and infrastructure – to track moving ground targets continuously.

Sensor Management. Increased progress in sensor management is needed to keep pace with growing needs for surveillance responsiveness and sensor richness as implied by Joint Vision 2010. More focused research and development in sensor management should address the challenge of real-time retasking, as necessitated by prosecution of "perishable" targets such as transporter erector launchers (TELs). Additional research and development is needed to confront the computational complexity of sensor management software when the number of sensors to be managed becomes large. Further discussion of sensor techniques and management is found in Annex J.

The Department needs to develop a comprehensive intelligence, surveillance, and reconnaissance (ISR) operational architecture that covers sensors, exploitation, tasking, and information management, in addition to communications and interface standards, and that integrates ground, air and space systems. Such an architecture is much more than communications, interface standards, and C^4ISR force structure, which is the apparent current

focus of ASD (C^3I). The operational architecture needs to make aggressive use of advanced technologies such as foliage penetration (FOPEN), automatic target recognition, high-resolution GMTI, and emerging high-value platforms such as endurance UAVs, micro UAVs and Discoverer II-like space-based radar systems. The architecture also needs to embrace the importance of real-time, wide-area data access and sensor management.

The DSB task force supports the Joint Discoverer II program because it promises to extend wide-area, near-continuous, all-weather sensing deep into enemy territory with near-continuous surveillance required for more effective military applications.

DoD is urged to ensure that as many GMTI radar as possible are upgraded to high resolution (1 meter or better) over the largest possible field-of-view. Only high resolution enables GMTI to support the recognition of moving vehicles necessary for precision targeting, or to support distilling moving-target detection to humanly manageable proportions. In this connection, the DSB also encourages support for the DARPA Moving Target Exploitation (MTE) program, which is developing automated techniques for recognizing vehicles from high-resolution GMTI data.

To complement wide-area GMTI radar, DoD should develop moving-target techniques – focal planes and processing techniques – for downlooking, staring electro-optic sensors. This would enable surveillance of "urban canyons" over relatively wide areas. Such a sensor would not see through clouds, but it could provide valuable information on traffic patterns and obstructions, and, when weather permits, it could provide real-time support to ongoing operations. The technology basis for this capability is already at hand, in the ground based-electro-optical deep space surveillance (GEODSS) sensors deployed worldwide for ground-based satellite detection. Development is needed to contend with additional complications presented by ground clutter.

The DSB supports the DARPA counter-camouflage, concealment and deception program, with its emphasis on FOPEN SAR and hyperspectral sensing. It is recommended that the program be expanded to encompass FOPEN GMTI. Without GMTI, targets that move under trees are virtually invisible.

The task force also suggests continued research and development into sensing in even more difficult environments, such as inside cities and underground. New emphasis should be placed on extending the capability to larger coverage areas in order to provide the warfighter with the biggest, most integrated picture possible. This will necessitate aggressive miniaturization to facilitate the widest possible sensor dispersal, as well as aggressive internetting to facilitate formulation of the "biggest possible picture." There also is a role for disposable "one-shot" sensors for battle damage assessment, for example, to fill niche sensing gaps where more sustained deployment is not practical.

The DoD should develop real-time sensor-rich sensor management techniques and support Service experimentation in sensor management. The operational tempo and comprehensiveness envisioned by Joint Vision 2010 make it essential to develop sensor management techniques that gracefully accommodate real-time dynamic retasking, and whose computational complexity is guaranteed not to grow explosively as the sensor population expands. DARPA should enlarge its program in ISR sensor management to address these issues.

INTEGRATED INFORMATION INFRASTRUCTURE

The essential foundation for capabilities discussed in this report is information superiority. Information, information processing, and communication networks — collectively, a distributed information infrastructure — are the core of virtually every aspect of military activity, including combat operations, navigation and geo-positioning, surveillance, weapons support, force enhancement, information control, and logistics support. Figure 17 depicts these interrelationships. Improvements in the distributed information infrastructure enhance the conduct of these military activities and enable the overarching goal of early and continuous combat effectiveness. The task force, therefore, believes establishing an Integrated Information Infrastructure is the key to realizing the knowledge superiority called for in this DSB study.

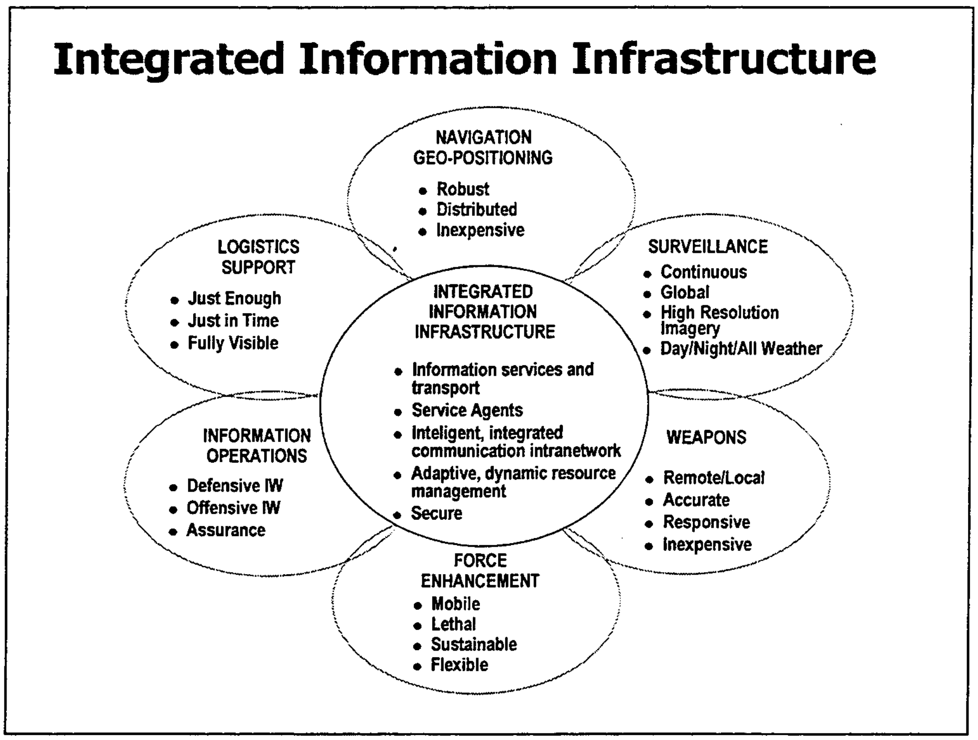

Figure 17. The Integrated Information Infrastructure Supports Diverse Military Activities

To realize the benefits of the enhanced operational concepts described in this report, a future information infrastructure needs to be capable of reliable transmission, storage, retrieval, and management of large amounts of data. Today's systems are linked to specific communications links, computers, and sensors that support specific functions, such as intelligence, logistics, or fire control. Furthermore, current systems are constrained by a lack of bandwidth necessary for high-resolution imagery transfer; processor capacity needed for target recognition and interpretation; memory sufficient to handle massive amounts of archival data; and software to search the many data repositories quickly in order to provide commanders with tactical information in a timely manner. These constraints are magnified by difficulties in integrating a myriad of legacy information systems with newly developed, service-unique and joint systems.

These limitations can be overcome by integrating individual military C4ISR systems into an interoperable C4ISR system-of-systems.

REQUIREMENTS

The task force vision is of a single Integrated Information Infrastructure serving all users consisting of:

- A multi-tiered, multi-connected transport network;
- A distributed computation environment; and
- Extensive use of intelligent software agents to help manage the network as well as empower the user.

As stated in Joint Vision 2010, military forces need to be able to receive or transmit all of the information it needs for the successful and efficient prosecution of its mission, from any point on the globe, in a structure capable of rapidly adapting to changing operational and tactical environments. The information infrastructure must support these needs, while allowing force structures of arbitrary composition to be rapidly formed and fielded. Furthermore, the infrastructure needs to adapt to unanticipated demands during crises and to stress imposed by adversaries.

To support the warfighter's needs, the infrastructure needs to:

- Provide assured, robust command communications linking all echelons
- Provide facilities to move information from any source to any destination
  - Sources = sensors => eyes and ears of soldiers
  - Information infrastructure = processors and communications => neural system
- Provide tailored information when and where required
  - Automatic data storage, retrieval, and management
  - Automatic data correlation and fusion
  - Intelligent information dissemination
  - Multimedia (images, video, text) information
- Facilitate force-structure tailoring
  - Ensures the interoperability of all Service C4ISR systems
  - Closes existing seams between military communication systems
  - Closes existing seams between C4ISR systems within and between Services
- Provide robust, reliable information services
  - Survivability through replication and self adaptation
  - Quality of service to meet dynamic requirements
- Not place warfighters at risk of being detected and targeted

CHARACTERISTICS

The information infrastructure includes multiple modes of data transport including land-line, wireless, and space-based elements. All of these media need to be integrated into a ubiquitous, store-and-forward data inter-network that dynamically routes information from source(s) to destination(s), transparent to the user. This data transport segment of the infrastructure needs to be self-managing, be adaptive to node or link failure, and provide services to its users based on quality-of-service requests. These services include bandwidths, latency, reliability, precedence, and distribution mechanisms (point-to-point, point-to-multipoint).

The infrastructure interface will link the user to a distributed processing environment that includes many types of computers situated at locations appropriate with their needs for power, environment, and space. This distributed computing environment will be integrated via the transport component of the infrastructure, thus enabling these processors to exchange data dynamically, share computation loads, and cooperatively process information on behalf of and transparent to the user.

The infrastructure integrates communication systems, computers, and information management resources into an intelligent system of systems. Each component of the Integrated Information Infrastructure exchanges state information with each other, in order to enable the entire infrastructure to adapt to user requirements and to stresses imposed on the network by an adversary. This adaptability also enables the infrastructure to change its scale as necessary to support force structure or to incorporate new processing, network, and communication technologies as they are developed. Thus, this infrastructure is a scaleable computing environment.

The information infrastructure must provide tailored information services to diverse users ranging from a single person to a collection of people, sensors, and/or weapons by means of intelligent agents – software entities, under the general control of the user, that are goal directed, migratory, and able to create other software entities, and provide services or functions on behalf of the user.

One or more intelligent software agents serve each user by *proactively* providing and disseminating appropriately packaged information. These agents perform such functions as fusing and filtering information and delivering *the right information to the right user at the right time*. The software agents are proactive in the sense that they are aware of the user's situation and needs and can provide information relevant to those needs without a specific user request. Figure 18 provides a conceptual rendering of these agents.

Software agents multiply the personnel resources available to combat units by gathering and transforming data into actionable information to support unit operations, just as combatants would have to do, were the software agents not provided. Warfighters are therefore freed of routine chores in favor of actual operations.

Because computing resources are distributed throughout the infrastructure, the infrastructure can adjust the amount of processing resources given to a force entity. The entities' processor need only provide access to the infrastructure, provide an adequate interface to the user entity, and enable the acquisition and presentation of information to the user. Thus, for example, a dismounted infantry person's information ensemble would be dedicated to supporting a rich

human-computer interface with voice recognition, heads-up display, speech synthesis, and communications. General computing resources would reside within the infrastructure itself.

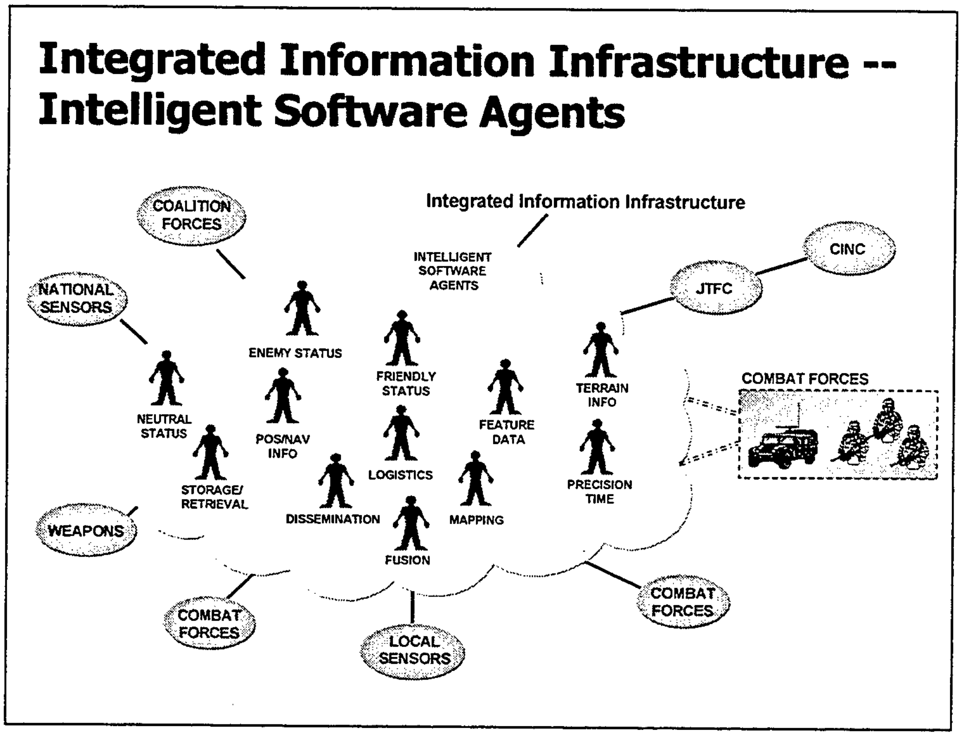

Figure 18. Intelligent Software Agents

To the maximum extent feasible, the infrastructure's transport layer takes advantage of commercial technology and networks by utilizing open-systems standards and protocols that minimize the use of Service or function-unique hardware and software. For applications where military-unique capabilities (such as anti-jam, low probability of intercept, or spread-spectrum waveforms) are required, military products will be developed or adapted to interface with the overall architecture. Figure 19 provides a conceptual summary of the entire Integrated Information Infrastructure.

IMPLEMENTATION AND PAYOFF

The task force believes a full-capability Integrated Information Infrastructure can be in place within 20 years, with a two-step approach to implementation. A baseline system, available by 2010, would be comprised principally of DoD-developed resources, with substantial augmentation of services and hardware from the commercial sector. This initial baseline can be characterized as having "military legacy" augmented by commercial resources. The final infrastructure, available by 2020, would incorporate significantly more commercial resources, diminished military-developed resources, and limited DoD-funded research and development to satisfy military-unique needs. Successful implementation will be dependent on leadership by the DoD Architecture Coordinating Council, with the USD(A&T) playing a principal role.

As it evolves, the Integrated Information Infrastructure will enable the following military capabilities:

- Geographic separation and functional integration of command, targeting, weapons delivery, and support functions;
- Support for split-base operations, force projection, information reach back, combat, and force protection for large and small units;
- Common situational understanding, common operating picture, and informed and rapid decision making for joint forces;
- Enhanced operational flexibility for commanders at all levels;
- Reduced logistics footprint in immediate combat area;
- Full exploitation of sensor, weapon, platform, and processing capabilities; and
- Real-time or near real-time responsiveness to commanders' requests for information, fire support, and urgent logistics support.

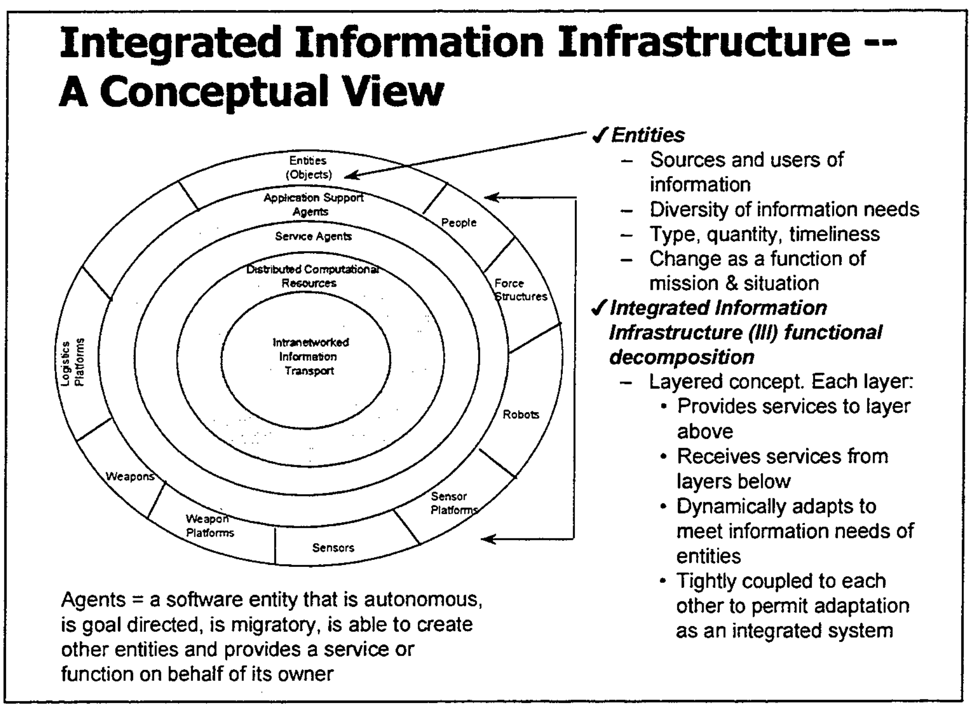

Figure 19. A Conceptual View

SUMMARY

A common Integrated Information Infrastructure is needed that will serve all military entities and functions and will permit the United States to exert, to the maximum extent possible, the power of its military forces in future contingency operations. It is critical to realizing the promise of Joint Vision 2010 and to achieving information superiority.

The DSB task force recommends that DoD develop, with the Under Secretary of Defense for Acquisition and Technology as the lead, a single information infrastructure for battlespace

awareness, logistics, targeting information, and command and control. The Integrated Information Infrastructure:

- Is based on a unified DoD-wide vision;
- Provides joint forces with common situational understanding; develops common operating pictures; and supports informed and rapid decision making;
- Integrates some legacy C^4ISR systems and exploits commercial information technology such as the Internet, personal computers, and satellite sensors;
- Is secure and provides information assurance by:
  - Making maximum use of commercial network and communication technologies;
  - Setting responsibilities and policies for developing and publishing joint operational, technical, and system architectures;
  - Establishing policy and procedures to exploit commercial information technology;
  - Setting milestone targets for deployment; and
  - Conducting evolutionary warfighter experiments leading to milestones, developments, and goals set for 2010 and beyond.

Annex K elaborates on the vision of the Integrated Information Infrastructure by providing a high-level perspective of several of its four layers, describing a detailed implementation strategy, and assigning responsibility within DoD for carrying out this strategy.

INFORMATION OPERATIONS

Information superiority is an essential element of Joint Vision 2010. The situational understanding that comes from superior information is vital in every stage of conflict – from early phases of crisis formation, through limited deployments or engagements intended to control events, and in fully developed, multi-dimensional regional combat. Information has always been important in warfare. The difference today is in the quality of sensors that can produce information, the speed with which information can be moved, the degree of reliance upon it, and the variety of methods for interfering with an adversary's information process.

In spite of enormous DoD investments in information systems, however, information superiority is not always achieved and cannot be taken for granted. Potential adversaries are likely to have a deeper insight into the complexities involved in a regional conflict. In addition, they know how much US operations depend on moving information around a battlefield. A variety of affordable and powerful tools are available that can enable adversaries to attack or deceive elements of the US information infrastructure. Further, the proliferation of commercial systems makes it possible for even smaller adversaries to employ sophisticated information techniques for their own purposes.

It is important for today's commanders to view the use of information, leading to knowledge superiority, as a key challenge and approach it in an operational context. In fact, the information domain has become an equal dimension of warfare, on par with land, sea, air, or space. Information operations, therefore, include attacking an adversary's information structure while

exploiting and defending our own. It also includes actions taken to provide information to public audiences on both sides of a conflict, shaping public perception. In other words, information operations include the full range of information protection measures (to include defensive information warfare), offensive information operations (which can include both hard and soft kill measures) and countering an adversary's propaganda messages.

A number of factors need to be considered in approaching the subject of information operations. They include:

- ***Offensive and Defensive Coordination***. Different disciplines are involved in offense and defense. There are sensitivities about cross-pollination of technologies between the two functions but, in an operational sense, there is an overriding need to integrate both dimensions into a coherent approach.
- ***Strategic Operation***. Offensive information operations, when conducted at the strategic level, involve important policy considerations and often require a high degree of inter-agency coordination. The policy and oversight processes need to be streamlined to be responsive. Exercises will be a key factor in achieving this goal.
- ***Immature Operational Concepts***. In spite of focus and attention on information operations in recent years, there have been few examples where it has been extensively and effectively integrated into major exercises or operations. In some cases, ideas have been oversold with resulting skepticism. Only further experience gained through experiments, exercises, and crisis operations will refine the concepts and prove their value.
- ***Classification***. To protect US offensive capabilities, many of the techniques and methods need to be classified at appropriate levels. Classification, however, can impede smooth coordination in an operational environment.

DEFENSIVE INFORMATION WARFARE

US communications networks, computer systems, the Global Position System, and many other systems have become both powerful instruments and potential targets. As exploiting information grows in importance, awareness of US dependency and vulnerabilities grows apace.

Vulnerability of communications circuits to exploitation or jamming is a long-standing problem. GPS is an example of the complexity of the modern problem. US precision targeting and communications systems will eventually depend on GPS for either navigation or timing, yet the system is vulnerable to even simple jamming. In another modern example, Internet technology provides powerful access to enormous amounts of information. It also provides an avenue for intruders to gain access to US systems – or for a disloyal insider to cause disruption. There are numerous examples of hackers successfully breaking into systems thought to be secure. Even with no malicious intent, there is a loss of confidence in the security of US information. A recent Computer Security Institute and FBI study documented a disturbing number of attempts and successful intrusions into systems, and experts believe that far more intrusions are made than are being detected and reported. Potential adversaries will realize the importance of information and will act (and invest) accordingly. Since, for the United States,

information superiority and knowledge superiority are key objectives, the issue of information protection is of utmost importance.

A broad and coordinated range of solutions is required and the topic is receiving much attention. Presidential Decision Directives 62 and 63 addressed this issue specifically. Previous Defense Science Board reports, as well as reports from other studies, have made recommendations.[16] It is worth noting, however, that the commercial sector also has much at stake. The banking industry is just one of many business sectors that depends on networks, and Internet commerce can only flourish if there is widespread confidence in system integrity. As a result, the commercial sector invests heavily in information protection technologies. Sophisticated programs, for example, are being developed that can detect irregularities in patterns of credit card or cellular telephone use. Since intrusion detection is an important step in addressing the problem, some of these technologies could have military applications.

For the operational commander, the problem has become complex. Attacks against the information infrastructure can be sophisticated and can be initiated far from the battlefield. Commanders need to ensure they have the doctrine, tactics, expertise, and real-time detection tools available to protect against this dimension of the threat.

Some specific suggestions for defensive information warfare include:

- In addition to actions already ongoing, ASD(C^3I) should review the full scope of protection efforts in the commercial sector with a view toward exploiting as much as possible for military operations.
- The Joint Staff, J-39, should continue to develop the operational perspective through strengthening information protection as an important element of joint exercises.
- USACOM should aggressively include information protection techniques in its joint experimentation program.

OFFENSIVE INFORMATION WARFARE

The object of offensive information warfare is to use information to mislead opposing forces and to leave them, at will, deaf, dumb, and blind. Also, offensive information operations could, and likely would, be conducted covertly to leave no fingerprints or to reveal how something was accomplished. US success in this area was a key contribution to dominance in the Gulf War. Future adversaries, however, will have access to much more powerful information sources, largely due to the proliferation of highly capable commercial systems. In fact, as the art of offensive information warfare matures, it is likely to be one of the first assets required in combat situations.

Although increasing attention has been given to individual tools in the offensive information warfare discipline, further development is still needed in the following areas:

- A sophisticated intelligence effort focused on the information networks and systems of potential adversaries. It should include nodal analysis techniques with a view toward identifying key vulnerabilities.

[16] *Report of the Defense Science Board Task Force on Information Warfare Defense*, November 1996, elaborates on this topic.

- Increased emphasis on deception planning and execution.
- Development of software weapons and the means to have assured battle damage assessment from an attack.
- Improved doctrine and tactics for integrating information weapons, sophisticated jamming tools, and precision attack conventional weapons against key network nodes.
- Better measurement and feedback methods. Deception and other indirect information techniques were used with great success in previous wars – even though the commanders who employed them could not be sure what effect they were having at the time.

Considerable interest and thought have been devoted to the area of information warfare operations by the Joint Chiefs of Staff, CINCs, Services, and selected Defense Agencies. At this point, however, the greatest gains are to be found in approaching the problem with clear operational objectives in mind. This approach starts with integrating the individual techniques into an overall campaign and experimenting with various scenarios. The Joint Staff's recent assignment of overall responsibility for this effort in J-39 is an important first step toward developing an effective operational capability.

Specific suggestions for further maturing information operations are:

- Consider modeling J-39 activities after the Joint Theater Air and Missile Defense Office (JTAMDO) model, to include integrated product teams and a master plan.
- Improve and exercise the intelligence process that supports this operational discipline. Offensive information operations require superb knowledge of communications networks, computers and software in use, nodal analysis, and encryption techniques.
- Increase the interplay between the National Security Agency, Defense Information Systems Agency, Joint Warfare Analysis Center, and Joint Command and Control Warfare Center. The latter two organizations will both report to USACOM, bringing synergy to the overall effort.

COUNTER PROPAGANDA OR EXPANDED PSYCHOLOGICAL OPERATIONS

In the post cold war security environment, US forces are frequently deployed to regional situations, but the mission often involves tasks other than defeating an enemy force in open combat. Disaster relief, humanitarian operations, peacekeeping, and peace enforcement are among the missions the military has recently been assigned. In disaster relief situations, the ability to communicate information and instructions rapidly and effectively to local populations in their native language is important to the success of the mission. In operations that involve intervention in regional conflict, however, an understanding of local cultures and the ability to communicate key messages to the various factions is even more important. Every side in a regional conflict will use local media and attempt to influence the world press. Some factions will try to put US forces in a bad light or incite terrorist actions against them when it serves their purposes. Bosnia was an example of an environment in which all sides attempted to inflame local passions in ways that made accomplishing US, UN, and NATO objectives more difficult. The

communications methods available to local factions are also getting more sophisticated. Cellular telephones, Internet access, and satellite TV are commonplace even in underdeveloped regions of the world.

Commanders need to consider the effects these propaganda campaigns can have in regional conflict. At a minimum, US commanders need the ability to counter the most damaging of the propaganda that will be used against them in these situations. Ignoring this dimension of an operation can contribute to a loss of local and international support, an increase in the threat of terrorist attacks, and an overall reduction in the chances of achieving mission success. Insensitivity to local customs and perceptions can turn otherwise neutral factions into active enemies as the Russians learned in their Chechnian campaign. Recent concerns about the proliferation of weapons of mass destruction bring the need for communicating key messages into even sharper focus. If the use, or threatened use, of weapons of mass destruction were introduced into a regional crisis, the effect it would have on all factions could be enormous and the ability to communicate messages of assurance or deterrence to affected populations could be pivotal.

The skills required may sound much like the missions assigned to traditional psychological operations (PsyOps) units, but envisioned here is something more sophisticated, more responsive, and more fully integrated into operations than today's psychological operations capabilities. The United States needs the ability to employ these techniques even before deploying forces, rather than attempting to phase in a counter-propaganda effort 30-60 days after deployment. Like other dimensions of warfare, success in counter-propaganda efforts depends upon good intelligence and advanced planning. This is particularly important since US forces are usually deploying to regions where adversaries will have a home-court advantage in terms of understanding both local issues and the communications infrastructure. Policy, doctrine, and planning disciplines need to be revitalized and counter-propaganda measures integrated into regional contingency plans. Failure to develop responsive and effective capabilities in this increasingly important area will limit the ability of future operational commanders to accomplish their missions.

In the area of psychological operations, the J-39 needs to initiate a joint, top-down review of the PsyOps mission. The review should address concepts, policies, inter-agency requirements, training, organization, and resource allocation. Questions addressed might include:

- Is the community keeping pace with changing technology?
- Does the intelligence community support the community's requirements?
- Is the doctrinal and tactical development program keeping pace with the changing demands of Joint Force Commanders?
- Is the community properly situated in the command structure?
- Does the exercise program support effectively integrating PsyOps capabilities into joint campaigns?
- Is funding sufficient to exploit the discipline's potential contribution to conflict resolution?

The US military is committed to the path of achieving knowledge superiority in the operational environment. There is a tendency, however, to allow the focus of this effort to center

disproportionately on improving battlefield sensors and information displays. In addition, operational concepts are becoming increasingly dependent on the assured availability of critical information. The field of information operations is focused on protecting US access to information, denying the same access to adversaries, and aggressively countering the propaganda that has been used effectively in a number of regional contingencies. Although a number of innovative concepts and technologies are emerging in this area, the ability to integrate this important dimension of warfare into a theater campaign is immature. An effective experimentation and exercise program led by USACOM is probably the single most important step to improve effectiveness in this critical area.

The DSB task force supports these initiatives and urges the Department to place even greater emphasis on information operations, particularly the protection of space-based systems and their terrestrial interfaces.

Responsive Global Targeting

One of the critical operational challenges described in this study is responsive, precision targeting on a global scale. The vision is the ability to unambiguously identify, classify and precisely locate potential targets; establish priorities for engagement; determine the desired effects; and provide the means to deliver the desired effect at the right point in space and time anywhere in the world. This concept requires advances in command and control, tracking and targeting, and engagement that together extend flexibility and effectiveness well beyond what current and near-term systems will provide.

Figure 20 depicts the enablers and the capability evolution for achieving responsive global targeting. There are significant technical and operational challenges that need to be addressed to achieve this ambitious goal. Some of the enablers required for responsive global targeting are also necessary to achieve early combat effectiveness and knowledge superiority.

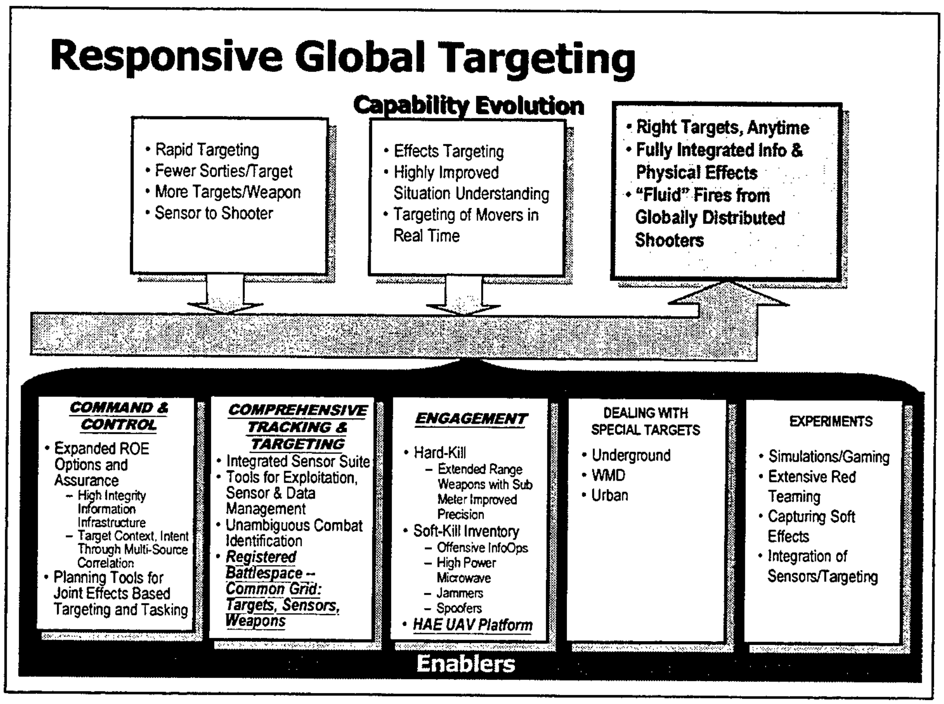

Figure 20. Responsive Global Targeting

This section describes several key enablers to achieving a revolutionary responsive global targeting capability: command and control, comprehensive tracking and targeting, registered battlespace system, engagement, and HAE UAV platforms. Other enablers are addressed elsewhere in this report.[17]

[17] Underground targets are addressed in Volume III. Weapons of mass destruction and urban targets are covered in Chapter 5.

COMMAND AND CONTROL

The speed and diffused nature of a responsive targeting system present commanders with new challenges as well as new opportunities. A commander is able to be far more effective when target tracks are produced by combining information from disparate sensors, when data correlation is increasingly automated, and when a positive hostile identification could result from the stream of information. In addition, the targeting system can become more agile and responsive. Since responsive targeting information will be provided simultaneously and in near real time to many commanders across the battlefield, a more responsive process of apportionment – deciding which weapon in which location shoots at which target – will be required. Automated means with high assurance, which allow the joint commander to quickly examine alternative courses of action, are required to facilitate these decisions. New concepts of operations need to be developed, which in turn are likely to result in modifications to command relationships. Joint experimentation and operational exercises are the right forum in which to examine these issues.

COMPREHENSIVE TRACKING AND TARGETING

Sensor and sensor management are expected to evolve to a point of providing near continuous coverage, high-fidelity signatures, and multiple viewing and signature phenomenology of all objects in the battlespace. The goal is to locate objects – to less than one meter error – from target designation to engagement. The challenge within the sensor network and the information infrastructure is merging many and disparate sensor data into continuous fire control quality track files that provide sufficient target identification, precision tracking, and supporting knowledge to a commander. The commander in turn uses this knowledge to bring the appropriate weapons to bear on any target, at any time, in any place.

An effective comprehensive tracking and targeting capability will require a number of improvements:

- Robust and assured availability of differential GPS and denying the same to enemies;
- Tracking algorithms that integrate multiple sensor data into all weather associations of move-stop-move, open to hidden, movement from one side of an obstacle to another;
- Automatic target recognition aids and tagging schemes that ensure unambiguous identification of all objects in the battlespace; and
- "Combat engagement capability-like" control algorithms that "lock" all participating sensors, weapons, and objects to a common time and space grid within the area of focus from initiating target designation through post-engagement.

DARPA's Moving Target Exploitation program is an example of a technology initiative that can help enable the envisioned comprehensive fire control-quality tracking of ground movers. The MTE program explores ways to enhance the contribution of one vital class of sensors – GMTI radar.

MTE is developing techniques to:

- Automatically initiate and maintain track and project movement of vehicles and groups of vehicles over interesting times and through complex situations, as shown in the top half of Figure 21; and
- Distinguish and identify moving targets, through high-resolution MTI radars (HRR) ID ATRs, and moving target imaging, shown in the bottom half of the figure below.

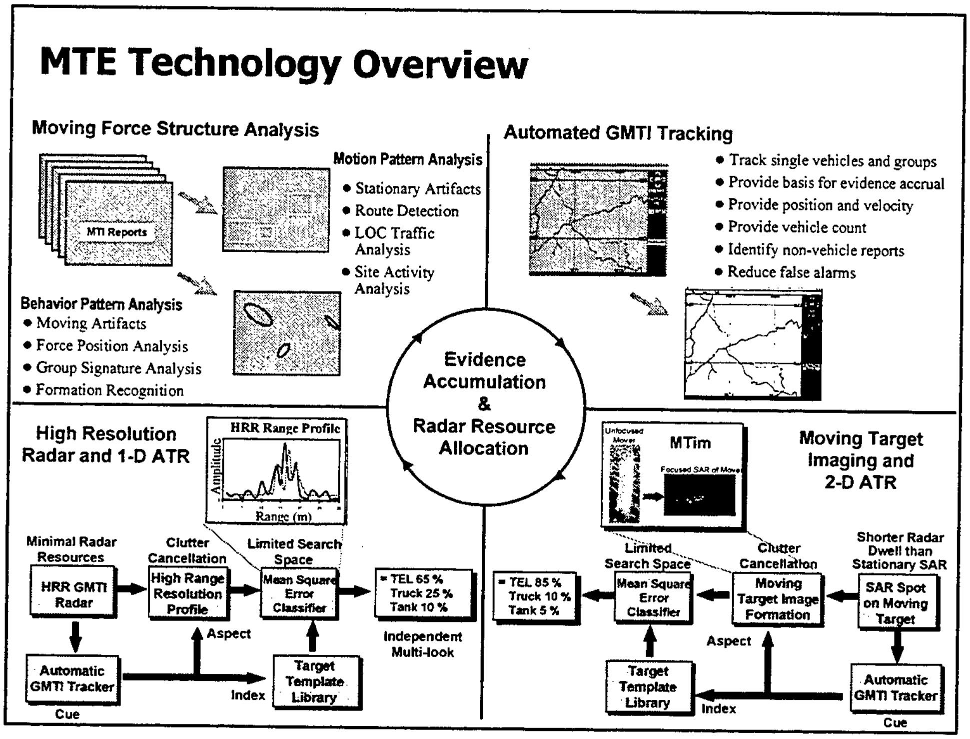

Figure 21. Moving Target Exploitation

The assumed reference for time and position object registration is differential GPS. The criticality of its role for supporting this and other operations throughout the conflict, such as timing, navigation, and precision guidance, demands that the system is available and resistant to jamming and spoofing. The global availability of GPS is introducing vulnerabilities to US and adversary warfighting postures. Measures to mitigate US vulnerabilities and exploit those of our adversaries will be crucial.[18]

The goal of continuous tracking represents a significant evolution beyond the current state-of-the-art of sensor exploitation and management as discussed earlier in this chapter. Linking and handoff between sensors to handle the many complicating cases of target behavior is critical. The sensor management system's control algorithms must recognize and act rapidly on such situations as targets moving into or out of foliage or structures, targets moving through mountainous terrain, targets starting and stopping and moving again, targets joining up with or splitting off from other targets, and similar target activity. The sensor exploitation algorithms

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18 Annex E contains an expanded discussion of enhancing and protecting GPS and Annex J contains an expanded discussion on sensors.

need to efficiently integrate and update track files as handoffs occur. The information infrastructure should be able to simultaneously support the disseminating of the track files to commanders, weapons in flight, and all intermediate users with the required information content, accuracy, and latency to serve the individual needs of each.

The foundation of successful targeting is unambiguous combat identification and classification – distinguishing, identifying, and classifying hostile targets from other objects in the battlespace. Advances in automatic target recognition are needed to progress from the near-term, SAR-based capabilities that address simple and/or stylized scenes to the more realistic cases of large numbers of targets in complex and changing environments. Complex target identification will place on ATR the same challenges for sensor management and fusion as for continuous tracking, with which it is synergistic and integral. Integrating such phenomenology as hyperspectral, video, and interferometric SAR will be required. In addition to ATR, a key contributor to combat identification will be tagging schemes, both electronic and physical, that should be given much more R&D and implementation attention.

At the heart of the vision for responsive global targeting is expanding the "sensor to shooter" concept to an architecture of fully distributed sensors and shooters, that are linked by the Integrated Information Infrastructure, and controlled through a dynamic, continuous, and adaptive command and control interface. A key technical enabler for this new capability is the ability to "lock" critical objects (sensors, shooters, targets, non-targets) into a common reference frame throughout the duration of the designation to engagement timeline. This is similar in notion to the cooperative engagement capability (CEC) currently being introduced into integrated surface fleet and naval air engagements. But it is dimensionally more complex with expansion to the combined ground and air battle and consideration of additional sensor and weapon assets that may be able to "play" in the operational context.

The DSB Summer Study task force recommends that the Department, with the Assistant Secretary of Defense for C^3I as the lead, integrate space-, air-, and surface-based sensors and associated tools for exploitation and management. Additional sensor development should focus on continuous coverage and obscured targets such as foliage, underground, or urban terrain.

REGISTERED BATTLESPACE SYSTEM CONCEPT

Prompt response to any global area requires an enduring, reliable, and precise navigation system to enable precise weapons delivery. Advanced satellite-based precision positioning systems, capable of navigation accuracy of one meter or better, such as wide-area differential GPS, will enable US forces to use relatively low-cost, all-weather, launch-and-leave standoff weapons to attack fixed and relocatable targets with high accuracy. This capability can be provided worldwide for US forces within two years of a decision to proceed. The determining factor for weapons accuracy becomes the accuracy with which the desired aim-point can be specified.

This capability was demonstrated during an effort undertaken in 1993 to investigate the possibility of achieving a three-meter CEP impact accuracy for the JDAM product improvement program. The technology inquiry pursued two possible solution sets: seeker improvements and/or navigation guidance improvements. Given that seekers have certain limitations, the

navigation guidance improvement path was pursued. Two possible solutions to improve navigation error were considered: the civilian DGPS system approach or the military dual-frequency GPS receivers. The DPGS system employs pseudorange corrections generated by a GPS reference receiver. This approach is limited in range since the user must remain within line of sight of the ground receiver. In contrast, the military GPS receivers are capable of using ionosphere-free pseudorange measurements that extend the range to greater than 1,000 miles. In this case, range is a function of maintaining visibility with the satellite that is receiving corrections from a regional ground station.

Using the latter approach in an Air Force-sponsored Joint Direct Attack Munition System Program entitled "Exploitation of DGPS for Guidance Enhancement (EDGE)," four ground stations were emplaced more than 1,000nm from the Eglin Air Force Base test range. Navigation corrections from the distant network were uploaded to a modified GBU-15 – a 2,000 pound glide bomb. In a release at 25,000 feet above an overcast, 1.4 miles from the target, the unpowered weapon hit within 2 meters of an aim-point.

As guided weapons use high-precision differential corrections to reduce navigation errors, and as guidance loops are optimized for minimum guidance error, the controlling factor for the weapon CEP becomes the accuracy of specifying the target aim-point location in three dimensional absolute coordinates (target location error). Minimizing this error will require integrating reconnaissance and surveillance assets that can produce DTED 4-5 level data and a referenced battlespace. The requirement has yet to be addressed or funded.

Target positioning accuracy of approximately one meter, with weapons delivery capability to match, will substantially alter weight-of-effort calculations, bomb damage expectation, and revisit rates. Implications for logistics are equally dramatic, driving down quantities of weapons; requiring much smaller stockpiles, storage, transportation and distribution needs; and lowering procurement quantities and funds. To the extent that such weapons can be standardized among user Services and coalition partners, smaller weapons buys can be aggregated for efficient purchases. This also leads to potential arrangements for sharing munitions and cross leveling stocks and other initiatives to reduce the cost of ownership while increasing availability on short notice.

GPS satellite clock and ephemeris error correction information can be transmitted to the military user/system/weapon through the GPS satellite's own navigation message. With this approach, the user's navigation system needs no additional datalink since the correction information is obtained using the integral capabilities of the receiver itself. This mechanism requires the involvement of the Navstar operating authorities to modify the control segment uplink data to the satellites. These technologies can be seen as functionally equivalent to providing a more precise positioning service GPS signal in space to the theater GPS user. For the near term, correction datalink schemes that do not involve alterations to the GPS control segment procedures should be considered. A variety of datalink schemes that link theater area surveyed GPS reference receiver networks with user receiver systems can be used, depending on the specific capabilities of the user receiver system platform.

The principal uncertainty in the implementation of this worldwide system is unhindered and enduring access to ground site locations outside of the United States for the surveyed GPS reference receivers. A possible but unlikely uncertainty is restricted access to subframe 4 of the GPS satellite constellation.

A militarized wide area differential GPS can provide the navigation accuracy necessary to support relatively low-cost, all-weather, launch-and-leave standoff weapons suitable for fixed and relocatable targets. Such geocoordinate-homing weapons can have high impact accuracy and thus achieve increased kill probabilities per sortie. This accuracy was demonstrated by a militarized wide-area differential GPS system in the Air Force EDGE program. With the availability of advanced techniques to provide accurate target location information in absolute coordinates, these weapons will dramatically alter military operations by providing high probability of kill per attack while substantially reducing the logistics pyramid for a campaign. Other significant applications could include mine warfare, precision airdrop, improved landing and terminal area guidance, and improved forward observer targeting.

The task force recommends implementing a military differential GPS-based "common-grid" to register targets, sensors, and weapons to a target location error of less than one meter.

ENGAGEMENT: NETWORK CENTRIC WARFARE

A new strategy is needed for target engagement capability, consistent with and leveraged from a new generation of integrated sensor capabilities, distributed interactive command and control, targeting based upon desired effects rather than any particular weapon, and a ubiquitous Integrated Information Infrastructure. This capability is achieved by providing the field commander with a family of weapons that share certain characteristics, but that complement each other in terms of basing requirements and delivered effects. The shared characteristics include minimal preparation time for targeting support, flexible basing requirements, and high precision delivery of desired disabling effects. This approach requires a departure from the "stovepipe" approach where a given weapon is "married" to a given sensor. Rather, weapons should require only the appropriate functional information for initiation and use, but should be virtually independent of the sources of that information, the particular sensors used to provide it, the Service or Services responsible for operating those sensors, or their method of basing.

The advantages of an integrated engagement capability in terms of force characteristics are well understood. The ability to deliver damaging effects with a high degree of precision on the desired targets translates to an overall reduction in collateral damage – important at all levels of conflict, but particularly important at the lower levels. It also means a reduction in the required number and aggregate tonnage of weapons that needs to be delivered to the theater. This latter benefit is compounded by a decrease in the logistics tail required. The benefits of distributing weapons on, near, and above the battlefield are leveraged by the disassociation of particular weapons from weapon-specific sensors and command and control elements. When coupled with the ability to deliver weapons from standoff ranges without compromising precision, fires from distributed locations can be massed with devastating effects. Lastly, the ability to deliver the appropriate weapon on the appropriate target at the appropriate time provides the commander in the field with an unprecedented ability to respond in a timely fashion to changing events with whatever constitutes the most suitable response. Thus commanders need access to weapons – both hard and soft kill effects – that can be used to neutralize targets from temporary disablement to total destruction.[19]

[19] The weapon toolkit could contain smart jammers, high-powered microwave devices as they become available, and offensive information operations techniques as well as precision bombs, missiles, and munitions.

Achieving an integrated engagement capability entails significant operational and technical challenges. Delivering weapons with sub-meter precision, particularly against moving targets, requires data networks and weapons with low latency. If the weapons are to travel long distances, yet with engagement accuracy characteristic of "zero time of flight," this low latency has to be maintained continuously. The concept of distributed sensors servicing a geographic and functional distribution of weapons through a distributed command and control network and an integrated information infrastructure requires the precise registration, both in space and in time, of all participating elements as discussed in the previous section. While this is not difficult to achieve in principal, doing so automatically on or above a moving battlefield with a myriad of multi-service warfighting assets has significant technical and organizational challenges.

A different and even broader dimension of this challenge is in the degree of interoperability that has to be achieved among all of the participating players. Again, the challenge is partially technological but has important organizational implications, particularly when addressing real time micro as well as macro interoperability between coalition partners, Services, sensors, weapons, and control elements. The objective should be to take expensive "smarts" (and cost, size, and weight) out of the weapon, and through proper force synchronization and offboard technologies such as GPS, allow the weapon to function using the precision built into the sensor and information network.

While these capabilities can be achieved in principal, it is prudent to acknowledge a number of uncertainties. First and foremost is the degree of precise interoperability and connectivity that can be realistically achieved across all of the dimensions discussed. Achieving such interoperability in a controlled experiment is one thing, in a true multi-element large fighting force another, and in the fog and turmoil of the battlefield is still another. A second concern is the feasibility of the planning tools necessary to provide the joint commander with a quick and reasonably accurate assessment of his options. Along with the flexibility inherent in an integrated engagement capability is the added burden of making and assessing far more choices than are available today within the rapid response time frame desired.

To counter this burden, the DSB task force suggests providing the commander a force operations tool that is equivalent to a "battle lab in a box." How to achieve this, capturing the scope of what is required, maintaining a realistic degree of fidelity, and providing the information to the commander in a short time without overwhelming him with indigestible information needs to be examined, developed, and tested. The effect of battle damage or reliability outages of individual equipment on the continued operation, precision, and viability of this fully networked method of fighting is also a challenge. The distribution of the individual elements should help, as will designing the integrating architecture in a way that avoids critical single point failure nodes. The system should be evaluated in realistic experiments to find unintended effects and undetected failure points and identify new vulnerabilities.

The Summer Study task force urges DoD – through the Joint Staff, the Services, and DARPA – to develop effective dynamic planning tools for: 1) seamless planning and execution of continuous operations and 2) targeting precision weapons and target allocation. These tools need to be developed within the network approach to warfare.

HEAVY LIFT HAE UAV PLATFORMS

Besides the airborne reconnaissance mission now envisioned for the High Altitude Endurance Unmanned Aerial Vehicle (HAE UAV), such as Global Hawk (TIER II Plus) and DarkStar (Tier III Minus), there are other potential combat missions for such platforms needing heavier and larger volume payloads.[20] These new missions include: the airborne sensor platform for a cruise missile defense system; the airborne sensor platform for a boost phase intercept ballistic missile defense system; the airborne receiver platform for a bistatic radar [called passive coherent location (PCL)] approach to battlefield surveillance of anything that moves; the airborne communications node and router for the multi-tiered Integrated Information Infrastructure described in the previous section; and a loitering weapons delivery platform to provide rapid response calls for fires against a wide spectrum of ground or surface ship targets. This latter mission is a high-altitude, long-endurance, precision weapons delivery system that can perform any of the missions currently envisioned for so-called Uninhabited Combat Air Vehicles (UCAVs). Stand-off weapons allow the HAE UAV to stay out of reach of enemy surface-to-air missiles and guns and simplifies the real-time command and control issues in managing the UAV platform and deconflicting the airspace.

The technology is available to develop a heavier lift HAE UAV with large volume payload bays. Payloads of 20,000 pounds are feasible while enabling the UAV to loiter for days depending on fly-out range from the UAV base to the combat zone. An HAE UAV in this class was examined in the DARPA TIER II Plus program.

For 21st century warfare, with the need to minimize loss of life and expensive manned aircraft, the DSB urges the Air Force to expand the roles and missions for large, high altitude endurance, heavy lift UAV systems.

SUGGESTED DEVELOPMENT INITIATIVES

In addition to many of the advances called out in each enabler, integration among enablers will be key to implementing a responsive global targeting capability. As such, these suggestions touch on both selected individual enablers as well as integrating efforts.

Precision Effects Architecture Development. The fundamental basis for responsive global targeting is the development of a precision effects architecture (operational, systems, and technical) which needs to include the functions of joint planning, targeting, effects assignment, and target engagement. The architecture must be consistent with, indeed serviced by, the Integrated Information Infrastructure and integrated with evolving sensor systems. Standards for interfaces between command and control elements, sensors, engagement systems, targets, and the Integrated Information Infrastructure need to be established. Developing this architecture should require about two years. Execution should be accomplished by a Joint Task Force team staffed by the principal strike planning schools in the Services: Air Force Red Flag, Army Battlelab at Ft. Sill, Navy Strike Weapons Center, USMC Warfighting Lab/Marine Aviation

20 HAE UAVs are high altitude (60kft to 80kft), long flight endurance, unmanned air vehicles remotely controlled through satellite communication links.

Weapons and Tactics Squadron-1 (MAWTS-1) and contracting support. The team should be directed by USACOM as part of their overall responsibility for joint experimental warfare.

Joint Precision Effects Operations Planning. To facilitate rapid joint planning, operational planning tools are needed to allow the timely assessment of and selection among options. This workstation-based capability is aimed at joint precision targeting for the Joint Task Force commander. Features to support rapid options assessment include movement and positioning of blue forces, blue force/red target ensemble pairing, built-in engagement simulators to provide "instant" feedback and assessment measures to the planner – in effect, a "battle lab in a box." The tool also enables push-button tasking to subordinate levels. The task force suggests that USACOM, with DARPA support, take the lead in developing a prototype of this tool through a two-year effort.

Weapons Modernization. The current inventory of strike weapons needs improvement to conform to the joint, distributed tasking and guidance environment envisioned. Many are amendable to upgrading. A two-step assessment is suggested. The first step is to evaluate the requirements for each weapon to evolve from a sensor-specific interface to one reliant on the Integrated Information Infrastructure (as specified in the Joint Tactical Architecture) and to upgrade its munitions/effects, precision, and range to meet projected new target sets.[21] Implementation with respect to cost, schedule, and risk, including requirements for new development, should also be part of this assessment. In the second step, a joint precision effects modernization plan would evaluate and integrate the results of step one to establish evolution, deactivation, common new development requirements, priorities among options, and funding and schedule assignments. Ownership for the task should be assigned to the USD(A&T), and the work executed over a one year period.

Advanced Weapon Concepts.[22] In addition to modernization, the task force suggests developing concept(s) and technologies for a new generation of longer-range precision strike weapons. These system concepts are to be designed from the outset to meet the goals of responsive targeting: off-board sensors interfaced via the Integrated Information Infrastructure to guide it to the target; GPS synchronization; minimum 100km range standoff; commonality and flexibility for multiple basing, delivery ranges, and payloads; precision delivery to sub-meter accuracy, and "zero time" targeting preparation. The "blank sheet" nature of this effort is well suited for assignment to DARPA, with Air Force and Navy participation. The recommended program would be in two phases: a two-year first phase for concept exploration and critical technology demonstrations; a second phase of three years for a system flight demonstration of a preferred or representative concept.

Experiments. The experiments critical to responsive targeting should focus on integrating the pieces outlined above with many of the elements recommended for the Integrated Information Infrastructure and dominant battlespace awareness to demonstrate joint long-range precision targeting and engagement. The framework for the experiments should be based on the precision effects architecture, and the experiment's command and control element should utilize the Joint Precision Effects Operations Planning prototype. Both existing and simulated modernized weapons should be included. Key factors for testing and understanding are the interfaces among the command and control, the tactical operations centers, the integrated information

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21 Annex K describes the concept of the Joint Tactical Architecture.

22 Volume II contains additional material on various advanced weapon concepts.

infrastructure, sensors and weapons, and the complexities of planning and tasking in this distributed, networked asset environment. The value of weapon modernization features, improvements in timelines, and the added flexibility provided to commanders are also important to assess. The experimental environment should also allow identification of conflicts, if any, among individual Service doctrines as they are tasked to operate in a truly joint targeting environment.

Exploiting the Littoral Battlespace

Influencing events overseas requires a credible, forward-deployed, power projection capability. The United States needs to maintain the capability to project power ashore against all forces of resistance, ranging from overcoming devastated infrastructure, to assisting a friendly people in need of disaster relief, to countering the entire spectrum of armed threats.

Forward-deployed maritime forces provide for scaleable expeditionary forces. These forces make a major contribution to the five key elements of the Joint Vision 2010 concept of operations to achieve battle space dominance. They are an asymmetrical strength that can respond expeditiously to changing and unexpected events.

Superbly trained, fully combat ready forces need to be able to globally deploy to a potential conflict within hours of the decision to do so. The ability to dominate the littoral battlespace will be critical to success in many likely contingency situations. This section addresses that complex operational challenge, as depicted in Figure 22.

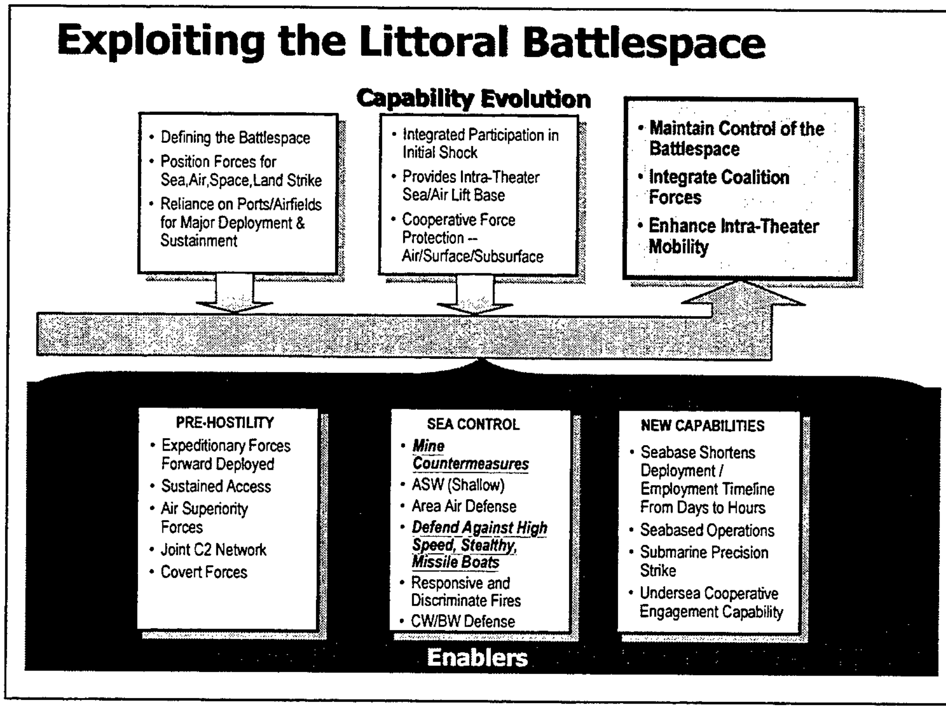

Figure 22. Exploiting the Littoral Battlespace

The top half of Figure 22 describes the evolving operational capabilities that are needed for exploiting the littoral battlespace. The enablers across the bottom of the chart build on the enablers needed for early and continuous combat effectiveness, assured knowledge superiority, responsive global targeting, inter- and intra-theater mobility, and other operational challenges such as urban operations discussed elsewhere in this report.

This section covers several of the key enablers required to achieve this capability: offensive naval mine warfare; mine countermeasures; and defense against high-speed, stealthy, covert missile and electronic combat boats. The important subject of chemical and biological warfare defense was covered in some detail in the 1997 DSB Summer Study "DoD Responses to Transnational Threats." Key recommendations pertaining to force and infrastructure protection are summarized in Chapter 5.

LITTORAL WARFARE

In many scenarios, US forces can expect to meet an adversary with capable area denial anti-access systems and operations to slow, degrade, or halt penetration to their shore from the sea. There is an evolving strategic competition between US global power projection and future adversaries who are enacting and projecting sea area denial and anti-access systems.

These anti-access systems include: long-range surveillance of the seas using space-based sensors and over-the-horizon radar; quiet diesel submarines; surface combatants; naval mines; high-speed, small boats armed with anti-ship cruise missiles; shore-based, long-range, anti-ship cruise missiles (both mobile and concealed); ballistic missiles employing radar terminal homing guidance to attack surface ships; and air and missile defense systems at sea and shore-based.

In a military context, littoral battlespace goes well beyond the narrow definition of the coastal region where the sea meets land. It also includes the adjacent land area that houses over three-quarters of the world's population, over 80 percent of the world's capital cities, and much of the marketplace for international trade.[23] While representing a relatively small portion of the world's surface, many future conflicts will be associated with the littorals, those areas characterized by great cities, well-populated coasts, and the intersection of trade routes where land and sea meet.

The littoral region is frequently characterized by confined and congested water and air space occupied by friends, adversaries, and neutrals – making identification profoundly difficult. This environment poses varying technical and tactical challenges to naval forces. It is an area where US adversaries can concentrate and layer their defenses. In an era when arms proliferation means some developing nations possess sophisticated weaponry, there is a wide range of potential challenges.[24] Air and missile defense of littoral areas of operation is discussed in the Theater Ballistic and Cruise Missile Defense section in Chapter 5.

OFFENSIVE NAVAL MINE WARFARE

With the exception of some small research and development initiatives at the Office of Naval Research, the Navy is pursuing only one new offensive mine initiative. That program is the Improved Submarine Launched Mobile Mine (ISLMM), which is jointly funded with Australia.

As part of the US Navy "tool kit" for littoral warfare, it would seem prudent to pursue development of modern naval mines. The 1998 DSB Summer Study task force concluded that

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23 US Marine Corps, Marine Corps Doctrinal Publication 3, *Expeditionary Operations* and US Marine Corps Concept Paper, *Operational Maneuver from the Sea.*

24 Department of the Navy, White Paper, ... *From the Sea.*

there is a need for more focus on the part of the Navy to equip the force with offensive naval mines designed specifically for support of operations from the sea.

MINE COUNTERMEASURES

Future operations will place a premium on highly mobile naval forces, with a responsive, mine countermeasure capability. With the shift in focus by naval forces from the open ocean strategies to the littoral regions, the potential for mines to frustrate operational plans has greatly increased. American forces need an effective mine countermeasures (MCM) capability to operate in distant waters in the early stages of regional hostilities; to protect vital follow-on sea lift containing supplies and equipment for the joint force; to allow swift littoral power projection operations; and to conduct follow-on clearance for humanitarian operations. Current MCM capabilities do not adequately support these requirements. The DSB task force urges the Department of the Navy to focus and sustain efforts on developing a viable and robust MCM capability. Annex L contains and amplifies on information extracted from the US Navy/Marine Corps concept for mine countermeasures.

In the aftermath of Desert Storm, American forces have done much to understand what went wrong with MCM. The current interest in MCM needs to be sustained to ensure support in the next crisis. Historically, the United States has not done well in the MCM area. Mines have dramatically demonstrated the ability to stall, disrupt, or thwart a naval force. Interest in mines recommences when problems arise during a war or conflict, but later, when budgets and force structure are reduced, countermine capabilities must compete for resources with higher-visibility programs, and interest in MCM wanes. The commander of the next war will have neither the equipment and assets of previous commanders, nor the time (reduced now to hours and days vice weeks) to conduct MCM to detect, identify, and breach or clear an enemy minefield that may be more sophisticated than that faced in the last war. Mines will be used in the next conflict; they remain a serious threat to US forces.

The DSB Summer Study task force recommends the following actions be taken by the Department to develop an effective mine countermeasure capability:

- Provide a commitment from DoD, the Department of the Navy, and Naval leadership to the evolution of mine countermeasures that will enable well equipped and trained MCM forces to be deployed in future military operations.
- Challenge the research and development community to develop a technology 'leap' and compress the development and deployment time of a family of efficient, affordable, and autonomous MCM sensor platforms.
- Elevate the priority of mine countermeasures:
  - Treat MCM as a co-equal among the major warfare mission areas by providing appropriate investment for both resources and manpower;
  - Develop realistic training mockups, simulation, and live MCM training ranges; and
  - Integrate MCM into joint, fleet, and coalition partner training exercises.
- Develop both supporting and organic MCM systems which are capable of:

- High area search rate with low false alarm generation sensors that are adaptive to the environment.
- Rapid deployment and employment with wide area detection, classification, and identification of mines.
- Rapid and autonomous mine clearing with minimal danger to personnel at sea and across the surf zones.
- Clandestine mine reconnaissance.
- Avoidance and in-stride mine and obstacle breaching from deep water to inland objectives.

- Develop an all-source, real-time, precision database which provides a common environmental battlespace picture for all MCM forces. It needs to have the capability to provide real-time environmental assessments and forecasts.
- Develop a C^4I architecture that supports the full range of MCM operations including: high data rate, near-real-time data exchange of intelligence and reconnaissance information that must be shared among all MCM forces and relevant command nodes.
- Develop self-protective measures including mine avoidance, signature manipulation, and shock hardening.

DEFENSE AGAINST HIGH-SPEED, STEALTHY, COVERT MISSILE AND ELECTRONIC COMBAT BOATS

A serious asymmetric threat against US control of the littoral sea battlespace could be the use of swarms of fast, agile, small missile boats. At the extreme small end could be dozens of single-man jet-ski boat-like vehicles armed with "Stinger" or anti-armor missiles deployed in a critical straight. High-speed, small boats of this sort could pose a significant harassing threat to US ships and helicopters. While the warhead size required to do significant damage to a surface combatant may require a weapon larger than an anti-armor missile, something that small can be used to attack surface logistic ships.

Another approach is to use larger boats, which are indistinguishable from local shipping crafts, such as junks, fishing boats, and dhows. In this case, the problem is not only defense against "swarming" attacks, but also identifying which are hostile craft, in time to destroy them. Such tactics were played in a US Navy war game a few years ago. The at-sea combat was in the Taiwanese Straights and the results were not favorable to US forces. Also, the junks and fishing craft employed acoustical noise makers to degrade US sonar. Small boats could also be used as platforms to jam communications and to jam air defense and surface defense radar and GPS receivers at close ranges to US surface ships. It would be quite difficult to sort out which boats or junks had the jammers.

For attacks in darkness or in poor visibility, the enemy might resort to brief use of active radar for target identification, acquisition, and range to target and launch an anti-ship surface skimming missile. For such threats, US surface ships need to be equipped with organic signals intelligence intercept and direct finding capability with automated signal identification and classification.

Inter- and Intra-Theater Mobility

Used in the broadest sense of the term, global force projection includes logistics and inter- and intra-theater mobility by sea, air, and land. A desired set of capability goals by 2010 and beyond for inter- and intra-theater mobility are captured in the box in the upper right of Figure 23. The enablers shown across the bottom include several major developments that will take sustained investment over the next ten to fifteen years.

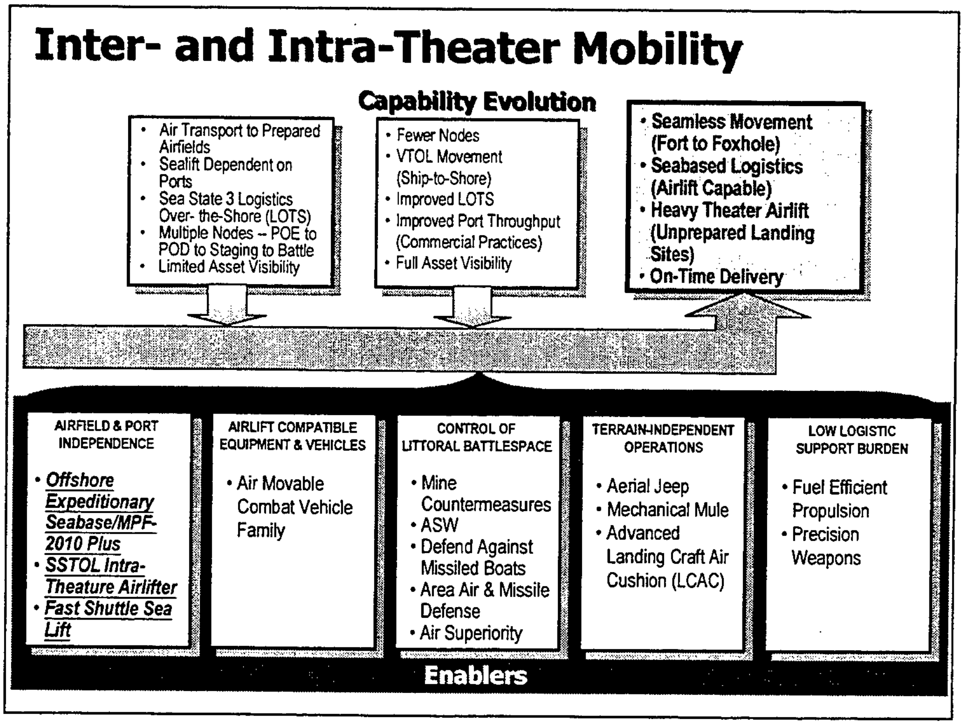

Figure 23. Inter- and Intra-Theater Mobility

This section discusses the following key enablers: an offshore expeditionary sea base called MPF-2010 Plus, a C-130 replacement in the form of a Super-Short Take Off and Landing (SSTOL) aircraft, and a fast ship-to-shore shuttle ship for off loading the MPF-2010 Plus ships. Many of the other enabling capabilities are discussed in Volume II or have been discussed earlier in this report.

INTER- AND INTRA-THEATER MOBILITY CONCEPT OF OPERATIONS[25]

Depicted in Figure 24 are current and potential future options to globally move people and equipment to and from the continental United States to theaters of operation. Across the top, strategic sea and airlift might move directly from CONUS into friendly, secure seaports and

[25] Volume II contains an expanded discussion of inter-theater airlift.

airports of debarkation (SPOD/APOD). While this is the most desired case, it may not be the most likely. Thus, the United States needs new capabilities such as sea-based operations and logistics areas into which strategic sea lift delivers people and equipment for onward movement to tactical areas. In some cases there may be a friendly third country in the littoral area with usable APODs and SPODs, that could also be serviced with the SSTOL aircraft and fast shuttle sea lift.

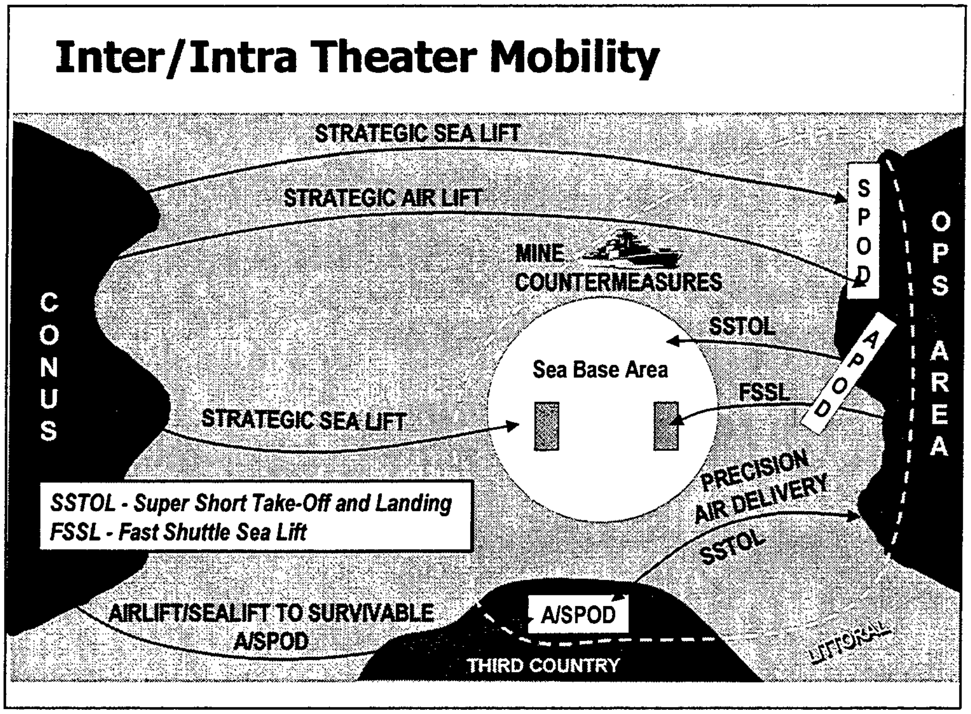

Figure 24. Inter- and Intra-Theater Mobility Concept of Operations

For either alternative, SSTOL aircraft provide a means to move forces and equipment to ashore landing areas (600 feet landing zone), and fast shuttle sea lift moves forces to the beach or small piers. The recommended addition to the planned MPF-2010 ship is an air-capable support platform with a 600 foot deck runway and a sea well to load and unload fast shuttle sea lift boats for heavy and bulky cargo.

Today, C-130 and sometimes C-17 aircraft provide the primary in-theater air mobility. However, the C-130 needs airfields with runways of at least 1,800 feet in length and 60 feet in width. Similarly, sea lift from the continental United States is dependent on large in-theater ports which are vulnerable to shut down by chemical or biological weapon attacks or by conventional weapons attack. In both cases, secondary distribution by truck is employed and forces and support must move through multiple nodes in the potential combat zone. Such land logistics distribution is less compatible with future non-linear land warfare concepts. Direct distribution by air from CONUS or from sea bases to terrestrial combat forces is needed.

In the mid term, logistics visibility can be improved with a combination of an improved data system and tagging containers which can be machine read as they progress through the logistics process. In addition, modern commercial port and airbase handling procedures can reduce trans shipping delays. Land-based ballistic and cruise missile defense systems are being developed to

provide protection to airbases and seaports but these systems themselves require heavy lift that is likely to be stressed during the first days of a conflict. However, ship-based area air and missile defense may be possible on the first day of combat with coverage well inland, depending on a secure littoral sea basing area and sea forces forward deployed based on strategic warning.

In the long run, an additional intra-theater logistics and mobility system is envisioned. This system would employ a combination of in-theater littoral sea bases (ships) capable of air operations, combined with a new SSTOL intra-theater aircraft capable of operations from sea or land bases into short, hastily prepared areas. These, in combination, would provide more freedom from missile threats but would still have to be protected from attack using naval forces capable of defending against undersea, air, and missile attacks.

The sea bases could also operate with new heavy-lift, high-speed, sea-ferrying craft capable of transporting bulky and heavy equipment and personnel ashore at high speeds. To enable this concept, the new family of combat, supply and troop ground mobility vehicles, described in Chapter 3 and Annex F, will also be needed. Additional reductions in logistics need to be made by designing all vehicles to be fuel-efficient through the use of new technologies such as improved gas turbines, fuel cells, and hybrid electric drives.

Offshore Expeditionary Sea Base: MPF-2010 Plus

The current Maritime Prepositioning Force (MPF) is a deployment option allowing forward Marine Expeditionary Forces (MEF (FWD)) – including a ground combat element, aviation combat element, command element, and combat service support element – to be rapidly deployed by air and united with prepositioned stocks of equipment and materiel stored in ships in forward theaters. The ships offload their stored equipment and supplies at an available port or in-stream using organic lighterage. These ships are designed for point-to-point delivery of administratively loaded containers and rolling stock. A large area on the beach is required to unload containers and associate the correct equipment and supplies with each unit. This process takes about 10 days in a benign environment before the MPF Marine Air Ground Task Force (MAGTF), a force of 17,000 Marines, is combat ready.

The goal of the MPF-2010 Plus concept is to provide a sea base from which combat-ready Marines can be deployed and sustained with minimum host nation support facilities. The MPF-2010 Plus ships will require capabilities that are not in the current ships, like accommodations for embarked Marines, assembly and staging areas, and facilities for command and control. Such a sea base permits Marines who deploy via the ships of a Maritime Prepositioning Ship Squadron to participate in Operational Maneuver from the Sea and Ship-to-Objective Maneuver. The forces committed ashore will be resupplied from the sea base, which will be replenished by Navy combat logistics ships or commercial ships. Also required is the capability to reconstitute and redeploy the MPF-2010 in theater.

The Requirement

Four "pillars" define the requirements of future MPF operations:

- Force Closure. Provide for the at-sea arrival and assembly of the MPF-2010 Plus ships, eliminating the requirement for access to secure port and airfields.

- Amphibious Task Force Integration. MPF will reinforce the assault echelon by providing facilities for tactical employment of assault support aircraft, surface assault craft, advanced amphibious assault vehicles, and organic lighterage through sea state three.
- Indefinite Sustainment. Provide indefinite sustainment by serving as a sea-based conduit for logistic support.
- Reconstitution and Redeployment. Conduct in-theater reconstitution and redeployment without a requirement for extensive material maintenance or replenishment at a strategic sustainment base.

This concept defines a requirement for a triad of functional capabilities that will provide the revolutionary leap in performance to meet the MPF-2010 Plus concept:

- A fast deployment capability to deploy the combat-essential equipment for a battalion landing team or similarly sized unit, along with a limited amount of palletized cargo.
- A reinforcement capability to deploy the equipment and 30 days of sustainment for a MEF (FWD).
- A sustained sea-basing capability to furnish the full range of logistics support and serve as a conduit from strategic bases to provide indefinite sustainment for the MPF MAGTF.

These requirements describe a greatly expanded function for MPF ships. Force closure implies accommodations on the ships for up to 17,000 Marines and an area on the ships for assembly and staging. Amphibious task force integration implies interfaces for air and surface assault craft as well as capability for selective offload of rolling stock. Indefinite sustainment implies selective retrieval and offload of cube cargo, air-based resupply of the ground combat forces, and replenishment of the sea base by commercial or Combat Logistics Force ships. Reconstitution implies an intermediate maintenance capability for aircraft and vehicles on the sea base.

THE MPF-2010 PLUS CONCEPT

The resulting ship design concept for the MPF-2010 Plus, as shown in Figure 25, is a single hull that combines an expanded air capability over the LHD/LHA Class amphibious assault ships, a well deck capability, and the capacity for preposition equipment as described in the requirements.[26]

[26] Annex M describes the key features of this ship in more detail.

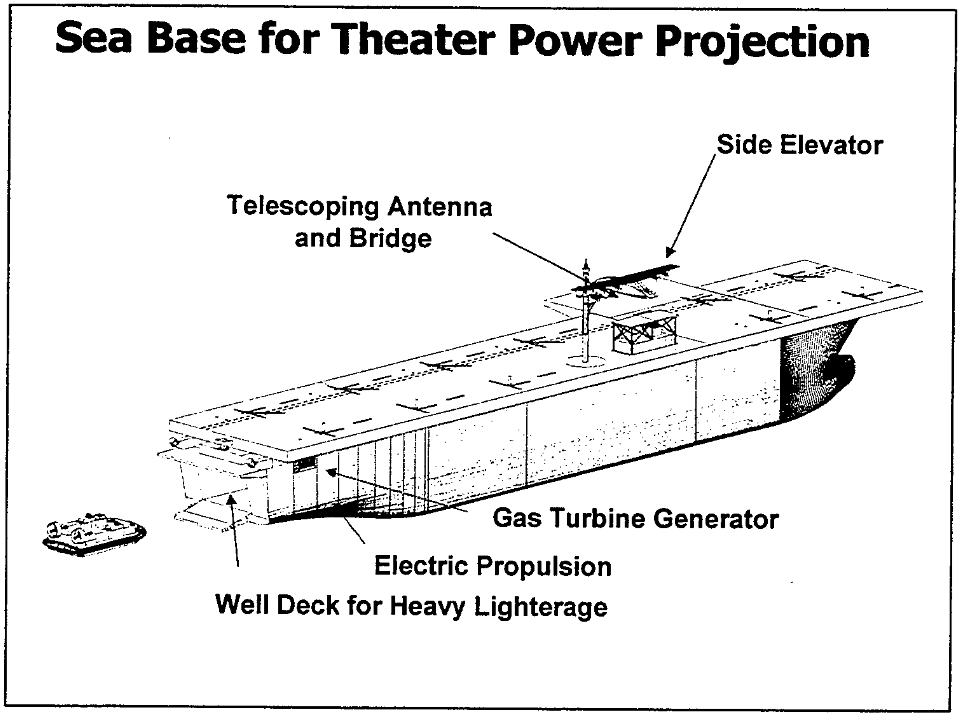

Figure 25. MPF-2010 Plus

Each sea base ship will carry 10-15,000 tons of Army and Marine Corps materiel as well as 2,000 troops. In addition to delivering cargo by air to the beach and directly deep inland, it is envisioned that this ship also have a wet-well from which cargo would be delivered simultaneously by waterborne craft such as the current LCAC designs and new fast shuttle sea lift ships. Together the air and ship delivery capability meets an offload rate of material of 400 tons per hour. Internally, the ship will be a sophisticated warehouse using modern material handling techniques driven by automated computer controls and computer-based information system software to achieve this desired offload rate.

To accommodate the mission requirements, a displacement of 55,000 to 65,000 long ton size ship would be required. The principal difference, in addition to size, over the current Navy amphibious ships is the increased sustainability built into the design. This would allow for longer on station operation without the need for continuous resupply. The amount of fuel, stores, and other consumables would be increased along with personnel support facilities for extended on-board deployments.

The ship design would take advantage of engine and computer technology – large aircraft derivative gas turbine propulsion engines and computer-controlled cargo handling and stowage systems – to both improve the mission capability and make it easier to construct. Today turbines in the 68,000 horsepower range are available for shore power stations and can be modified for marine use. Instead of the three large, maintenance-intensive boilers and two steam turbines used on the LHD, the MPF 2010 Plus ship would have two gas turbines that could be replaced in a matter of hours if needed.

The propulsion plant arrangement would be an element of an electrical integrated power system. The propeller would be driven by a large electric motor located deep in the side hulls

with the gas turbine generators located higher in the hulls. This plant arrangement eliminates one of the major design issues for amphibious ships – the long propulsion shafts needed to accommodate the well deck in the stern of the ship. With the gas turbine generators located higher in the hull, the penalty from large air intakes and exhaust ducts can be minimized.

Designs for computer-controlled cargo handling and stowage systems would be based on current commercial cargo systems but would require development for application at sea. The ship would require load ramps and decks for wheeled vehicles plus elevators, monorails, and other conveyor systems for palletized cargo and ordnance. Key to the effectiveness of the ship is the ability to rapidly handle cargo and reconstitute supplies and equipment for direct use by forces ashore.

To create a clear flight deck for the SSTOL aircraft, the ship will be designed with two new features: a telescoping bridge equipped with electro-optic sensor displays, and telescoping large multi purpose radio and radar mast.

The remaining design for the well deck operations, troop berthing and support, and aircraft support would be similar to today's amphibious ships. The flight deck is sized to meet the requirements of the new SSTOL aircraft. Giving the landing requirement of 600 feet and the need for elevators and parking space, the ship length would be about 1000 feet but without the need for aircraft launch and recovery systems found on today's nuclear aircraft carriers.

The DSB recommends developing the MPF-2010 Plus. At this early stage, it is estimated that ship follow-on cost, without the up-front research and development design costs, will be $1.5 billion per ship.[27]

SSTOL INTRA-THEATER AIRLIFT

Intra-theater airlift operations will be required to move and resupply troops at forward, austere areas to reduced dependence on operations at fixed airfields. A SSTOL advanced theater transport is one concept that enhances both force deployment and force engagement. Both the Army and the Air Force have independently identified the need for a SSTOL airlift.[28]

The Air Force sponsored numerous trade studies to examine future tactical airlift concepts. The Advanced Theater Transport Mobility Analysis program analyzed concepts for three combat delivery categories: Vertical Takeoff and Landing (VTOL), Super Short Takeoff and Landing, and Short Takeoff and Landing (STOL). In one series of studies, 44 advanced concepts were investigated. Subsequently, 24 advanced concept designs were developed and analyzed. Each design was sized for identical mission payload and range requirements. Trade studies were conducted, the results of which are summarized in the table below. In general, the study concluded that a tilt-wing SSTOL concept was preferred.

[27] Subsequent to the task force deliberations, the FY99 National Defense Appropriations Conference Report has provided $10M in FY99 for maritime prepositioning ship research and development to begin work on a new ship design to meet MPF-2010 requirements.

[28] The Army need is documented in TRADOC Pamphlet 525-66, Future Operating Capabilities; the Air Force need is documented in the AMC Air Mobility Master Plan.

	Total Fuel	*Weight*	*Landing Dist*	*Cargo & Support*	*Total Cost*
VTOL	○	○	●	◒	○
SSTOL	●	◒	◒	●	●
STOL	◒	●	○	○	◒

● **Best in class** ○ **Worst in class**

Another significant finding was that the capability to operate in austere, unprepared areas dramatically increased the number of landing sites available for operations. The correlation between landing distance and opportune landing sites was not linear, but ranged from relative few for STOL, many for SSTOL and VTOL, but not a significantly greater number for VTOL over SSTOL. The tactical advantages of opportune landing sites combined with the characteristics of an SSTOL-category air vehicle made a compelling case for its preference over the other configurations.

Force deployment directly to staging areas can be accomplished via SSTOL airlift and sea bases. The SSTOL airlifter and an offshore sea base permits the sea base to operate in reach of available staging bases but beyond the reach of short-range enemy attack, while exploiting the pre-positioning capacity of the sea base. A payload of 40,000-50,000 pounds would allow insertion of light armored forces, support forward operations of Advanced Short Take-Off/Vertical Landing (ASTOVL) combat aircraft and helicopters, and deliver fuel, munitions, and supplies. Ability to land and take off from a 600-foot ship deck without catapult or arresting gear reduces development risks and build costs for the ship (compared to the Mobile Offshore Base concept). Capability to land on unprepared landing sites enables access to more operating sites than an enemy can afford to target. The aircraft will also be able to return without payload from the staging base to the sea base.

Force enhancement is dramatically improved with the speed, range, and flexibility enhancements afforded ground forces with the SSTOL airlifter. Dominant maneuver is predicated on information dominance *combined with* the ability to sustain high tempo, precision combat engagement. The Army After Next concept of air mechanization is to reposition decisive firepower by airlift around the battlespace to gain advantage of position and compel an adversary to either react from a position of disadvantage or quit. An SSTOL Advanced Theater Transport is an enabling concept for air mechanization.

Resuppling a widely dispersed, logistically tailored, high tempo ground force is also a critical challenge. High operational tempo and responding to real time information dominance will make the future battlespace far more dynamic than traditional warfare. Direct to foxhole resupply can be accomplished by an SSTOL airlifter to either opportune landing sites or by precision airdrop.

One SSTOL concept is a four-engine, tailless, wide body, swept tilt-wing aircraft. It combines outsized cargo lift and volume capacity with the ability to self deploy to austere operating locations and sustain airlift operations there without supporting material handling equipment. The design payload ranges from 33,000 pounds at 3.0 g to 69,000 pounds at 2.25 g. Its nominal unrefueled range is approximately 3000 kilometers with a 69,000 pound payload to a

ferry range of approximately 7400 kilometers. It is powered by four cross shafted turboprop engines in the 8000-11,000 SHP class. The conceptual design was sized by a perceived Army After Next mission to airlift 50,000 pounds a distance of 1000 kilometers, land in a 600 foot unprepared landing area, and return to the takeoff point.

The general arrangement of this SSTOL airlifter is shown in Figure 26. Innovative control effectors, that span the trailing edge of the wings, provide stability and control. The SSTOL airlifter has the capability to select and display suitable landing sites using onboard databases and sensors. This enables the pilot to rehearse and then execute opportune landings at night and in adverse weather.

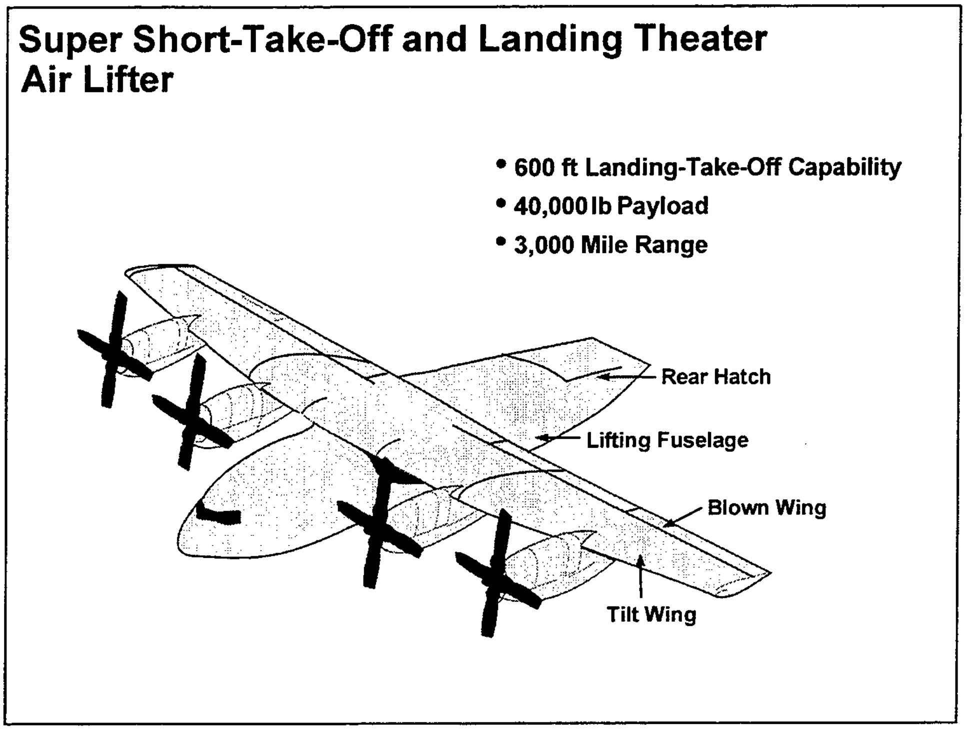

Figure 26. SSTOL Concept

The cargo box size is 21 feet wide, 13 feet high, and 49 feet long. It can accommodate most modern military loads including International Standards Organization (ISO) containers. The cargo ramp is articulated to unload cargo directly to Army trucks at any truckbed height. Pallets are loaded and unloaded directly from trucks via powered roller tines, which retract into the ramp. Cargo/pallets/containers are translated throughout the cargo compartment by a powered belt system. ISO containers can be loaded or unloaded directly from container trucks, flatrack trucks, or the ground by a unique overhead winch system. Autonomous cargo handling efficiencies are critical to high throughput. It also eliminates the need to transport material handling equipment shipboard or to austere sites.

The DSB task force recommends that the Air Force and DARPA begin concept definition of a new intra-theater transport with a desired initial operational capability of 2015. The new transport should be shipboard capable of launch and recovery with payload range, volume, and weight comparable to the C-130J-30.

FAST SHUTTLE SEA LIFT

Fast shuttle sea lift has the capability to rapidly project a viable combat force ashore and then sustain the force for an indefinite period of time, providing deterrence and a potent, balanced combat capability. As part of a strategic joint force, this capability has relevance across the spectrum of conflict – from humanitarian or peacekeeping missions to a major theater war.

The concept for a fast shuttle sea lift ship, examples of which are shown in Figure 27, provides a vital link between the sea base and the combat operations area ashore as well as potential intra-theater arrival and assembly or distribution areas on friendly territory. Even with advanced aircraft such as the SSTOL, discussed in the previous section, the amount of cargo that can be timely delivered by air will not satisfy the requirements of the joint force commander. Moreover, US forces cannot count on delivery of equipment and supplies to modern seaports. Although geography and weather effects favor airlift deliveries on occasion, mass delivery of large supplies will generally require sea lift. Finally, the fast shuttle sea lift capability provides a viable means of resupplying the sea base from the continental United States, intra-theater sources, or other support ships.

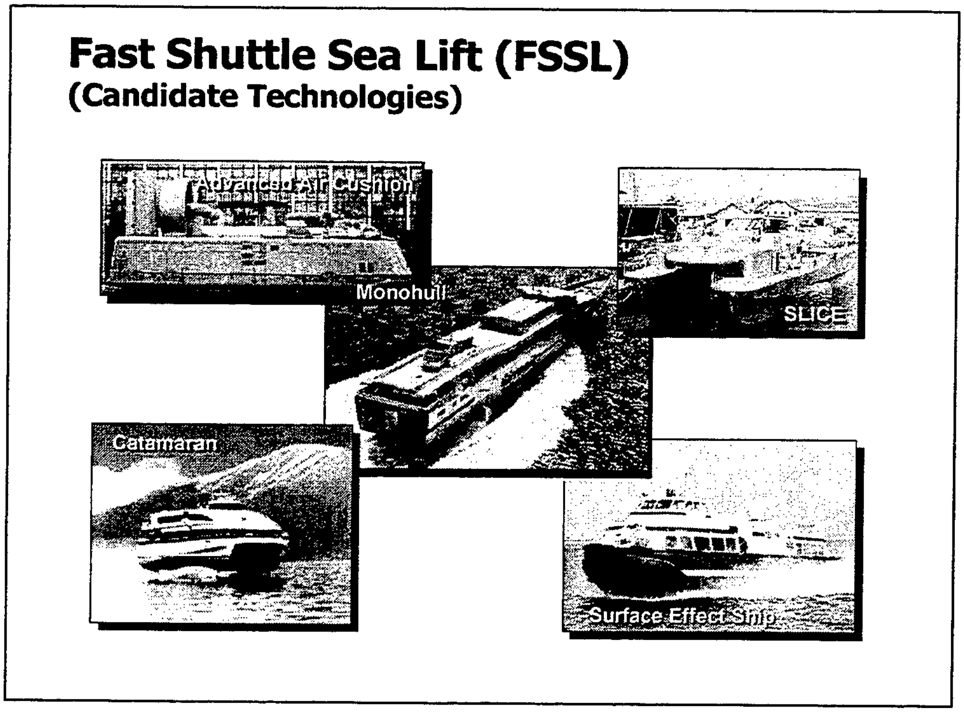

Figure 27. Fast Shuttle Sea Lift Technologies

New intra-theater vessels need to be capable of lifting heavy cargo and vehicles over relatively short distances (1000-2000 nm) and at high speeds (40+ knots) in a sea-state three, or worse, environment.[29] Several emerging technologies offer the potential to satisfy this requirement; however, a family of compatible intra-theater sea lift assets may be the best solution.

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[29] Annex N elaborates on the fast shuttle sea lift concept.

- Small Waterplane Area Twin Hull (SWATH)/SLICE sea craft for stability in heavy seas and high-speed resupply of the sea base. A SWATH/SLICE vessel that has the capability to quickly deploy erectable causeways, conduct intra-theater resupply, or offload ships would provide the greatest benefits.
- Advanced surface effect craft for ship-to-shore movement over unimproved landing sites.
- Advanced air cushion landing craft – with potential folding "gull wing" technology to reduce embarkation space – as a replacement for the aging LCAC.
- Quickly erectable causeways that can be self-deployed from other fast shuttle sea lift vessels – potentially the SWATH/SLICE vessel.
- High-speed advanced lighterage capable of offloading equipment and supplies from ships or the offshore expeditionary sea bases and then landing on varying beach gradients. This lighterage should also possess the capability to operate with expeditionary, quickly erectable, causeways deployed from other fast shuttle sea lift craft.

In order to provide a balanced capability, all of the fast shuttle sea lift technologies should be compatible with the offshore expeditionary base, commercial ships, and legacy military ships such as amphibious ships and combat logistics force ships.

Deployment and employment options for the fast shuttle sea lift vessels will depend upon the development of the offshore expeditionary base and its associated deployment/employment options. The favored option includes a robust fast shuttle sea lift capability that is resident on the offshore expeditionary base and augmented by other ships that possess a smaller capability. However, a rapid self-deployment from CONUS (without embarked supplies) capability should not be ruled out for the larger SWATH/SLICE intra-theater fast shuttle sea lift vessels. Likewise, an independent forward presence capability – in addition to the assets on the offshore expeditionary base – may prove to be a worthwhile investment.

These new shuttle sea craft will enable sea-based operations independent of major ports. Also, this will allow an increased logistic tempo while at the same time increasing the protection of material at sea prior to a shore delivery by keeping these "warehouses" of combat/logistic materiel at greater distance from shore. The basis for this increased tempo stems from the development of high speed (40 knots), heavy payload (10 times the current LCAC unit payload) small ships coupled with the ability to quickly erect causeways to mate with these small/fast special ships.

The Summer Study task force recommends that the Navy undertake development of a fast shuttle intra-theater sea lift ship – with an initial operational capability in 2010 – to operate with the MPF-2010 Plus sea base concept.

CHAPTER 5.

Supporting Operational Challenges

Joint operations involving coalition partners are becoming the norm ... Force protection ... is an important element of effective future operations ... The increasing availability of ballistic and cruise missiles ... means that explicit attention to defense against these weapons needs to be a priority ... Urban operations should be treated as a likely operational environment.

CHAPTER 5.

Supporting Operational Challenges

This chapter discusses four supporting operational challenges: coalition warfare, force protection, theater ballistic and cruise missile defense, and urban operations. These four capabilities are the topics of past or ongoing DSB studies, referenced in Annex A. While they are covered in somewhat less detail than the primary operational challenges in Chapter 4, this DSB task force wants to emphasize their importance in underwriting Joint Vision 2010.

Joint operations involving coalition partners are becoming the norm, but in the future these partnerships are likely to be formed on an ad hoc basis rather than from established relationships. Force protection, emphasized in the 1997 DSB Summer Study, warrants mention again as an important element of effective future operations. Addressing US vulnerability to transnational adversaries is an ongoing concern for the nation, as was evident by the embassy bombings in Africa that occurred during the Summer Study deliberations. The increasing availability of ballistic and cruise missiles to potential adversaries means that explicit attention to defense against these weapons needs to be a priority for the Department. Finally, urban operations should be treated as a likely operational environment. The following sections review each of these areas.

Coalition Warfare

As the US pursues new military capabilities to deal with 21st century challenges, it also needs to retain the ability to conduct military operations with its allies and other potential coalition partners. How to meet this challenge is the subject of an in-progress DSB task force that will report its findings and recommendations later this year. This section highlights this critical challenge and suggests several steps the DoD can take to meet this challenge.

DoD needs to devote sufficient attention to the challenge of preparing for tomorrow's coalition operations. Gaps, both perceived and real, present obstacles to future coalition operations. US allies complain about a growing technology gap. While there are gaps in technology between the United States and its allies (and much larger technology gaps with other potential coalition partners), technology gaps are not the major problem. In fact, technology, through the increasing global availability of state-of-the-art commercial information systems, can be an enabler of, not an obstacle to, future coalition operations. Of more concern are other emerging gaps with traditional US allies and other potential coalition partners – gaps in resources devoted to modernization, in military strategies, in perceptions of future threats, and most pertinent to the topic at hand, in the pursuit of new concepts of operations and doctrine. A growing doctrinal gap will make it increasingly difficult for any partner to participate in a militarily substantive manner with the United States in the future.

The United States needs to pursue Joint Vision 2010 capabilities aggressively to widen the gap with potential adversaries while preserving the option to conduct military operations with future coalition partners.

Coalition operations can include a wide range of contingencies – from major theater war to humanitarian, peacekeeping and other lesser contingencies – and encompass an equally wide variety of partners (from traditional allies to temporary arrangements of convenience). The United States cannot have a single strategy for coalition operations, but should instead tailor its strategy to account for differences in coalition relationships.

In addition to coalition operations, the DoD needs to pay more attention to operations involving interagency players (State, Justice, DOE, and civil authorities in other nations) in peacekeeping, humanitarian, counter-drug, and other "lesser" contingencies. A possible useful step to facilitate the creation and conduct of future interagency and coalition operations is to establish standing task forces. The purpose would be to develop the command and control relationships, foster trust through familiarity and working relationships, and work on mitigating the obstacles that impede successful interagency and coalition operations. The primary purpose would be to create an ongoing basis to provide for interagency and coalition operations when they are needed. The evolution of such a combined Task Force is depicted in Figure 28 along with a list of some of the enablers.

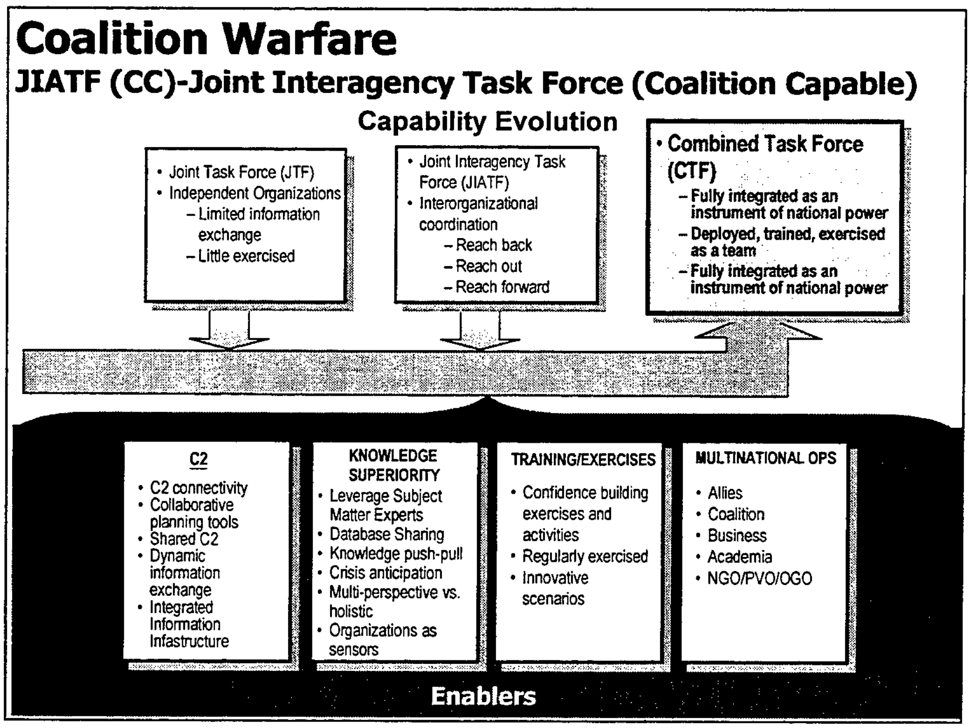

Figure 28. Coalition Warfare

A key enabler of a combined Task Force is a coalition friendly information infrastructure. Development of the Integrated Information Infrastructure that is recommended in Chapter 4 should facilitate interoperability with allies and coalition partners. The United States also needs to pursue the implementation of common data structures. This would facilitate the creation of a

hierarchy of "common" operational pictures that could allow tailored levels of two-way knowledge sharing with coalition partners.

Other enablers include:

- Establishing mechanisms to facilitate information sharing in exercises and operations;
- Building long-term people-to-people relationships, which foster trust and provide the foundation for effective coalition operations;
- Involving close allies in the early stages of concept development and experimentation; and
- Involving allies and their industries in surge transportation and communication capabilities based on commercial systems.

Two areas that may be particularly suited to longer-term cooperative activities with other nations are defense against theater missiles and countering weapons of mass destruction.

Force and Infrastructure Protection

The 1997 Defense Science Board Summer Study on *DoD Responses to Transnational Threats* examined the issue of force and infrastructure protection. Highlights of that assessment are presented in this section. Figure 29 shows an evolution of force and infrastructure protection capabilities, leading to the characteristics of full-dimensional protection. The force protection environment has in the past focused primarily on perimeter security and high-explosive detection and response. More recently, the Department has placed a renewed emphasis on the command element of force protection calling for energy and resources directed toward: assigning key command responsibilities; training and developing operational skills for force and infrastructure protection; establishing standards to combat transnational terrorism; and producing expanded vulnerability assessments. Full-dimensional protection, as envisioned in Joint Vision 2010, should encompass: multi-layered protection of forces; seamless joint architecture for command and control of force and infrastructure protection resources (active and passive, military and civilian); and increased emphasis on detecting, protecting, and defeating chemical, biological, nuclear, and radiological weapons in urban, military theater, and non-military environments. Five key enablers are summarized in this section – mission responsibility, vulnerability assessments, organization, technology and training, and intelligence operations.

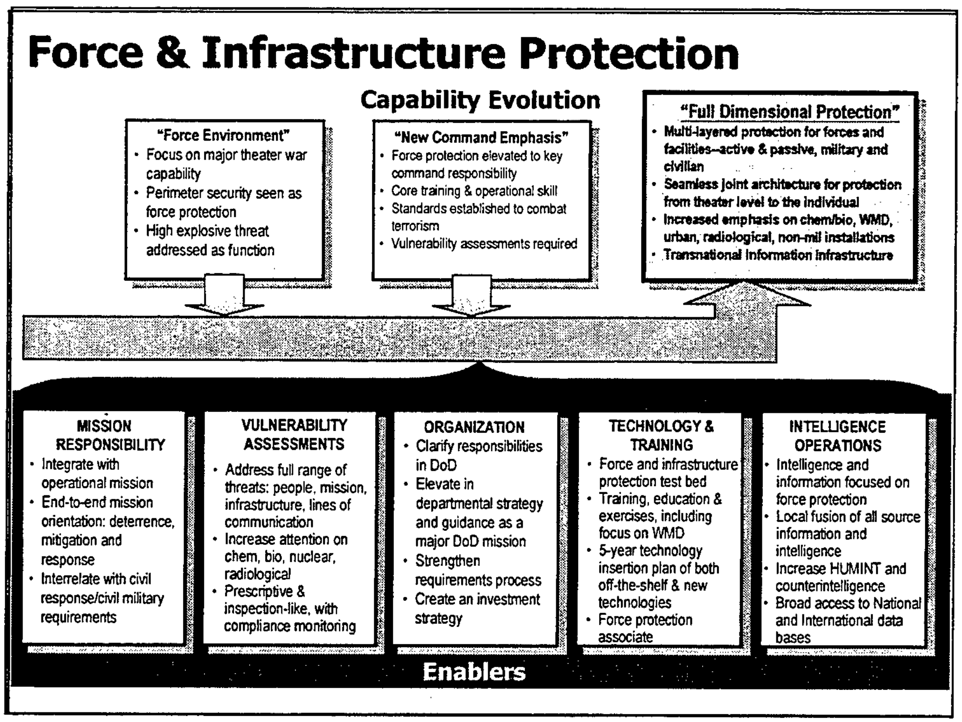

Figure 29. Force and Infrastructure Protection

The transnational threat is a major challenge for the US military and will remain so in the future.[30] US presence, policies, and leadership must remain a major stabilizing force in the world, requiring a range of credible offensive military capabilities and independent or coalition operations. A credible future global model depicts an environment that will require an activist foreign policy to sustain world stability, continuing foreign presence, and occasional military interventions in areas of conflict. This same model exacerbates stresses that traditionally motivate transnational adversaries.

In response to the Khobar Towers bombing, the Secretary of Defense directed a number of immediate actions to be undertaken to deal with this emerging model of transnational terrorism. As a result of these directions, new directives have been put in place and new responsibilities have been assigned, with the Chairman, Joint Chiefs of Staff as the DoD-wide focal point for force and infrastructure protection; and the J-34 as the Joint Staff Directorate responsible for combating terrorism.[31]

The 1997 DSB Summer Study made six major recommendations:

- Treat transnational threats as a major DoD mission.
- Use the existing national security structure and processes.
- Define an end-to-end operational concept and system-of-systems structure.
- Provide an interactive global information system on transnational threats.
- Address needs that have long been viewed as "too hard."
- Leverage worldwide force protection and civil protection.

Each of these recommendations has been acted upon to one degree or another and the DSB is encouraged that even greater progress will continue to be made. In the specific area of force protection, the 1997 Task Force made the following additional recommendations:

- Emphasize force protection as a mission responsibility;
- Expand scope and breadth of vulnerability assessments;
- Demand synergy among policies, plans, and programs and create an investment strategy;
- Frame a five-year technology plan around an architecture study and integrated technology test bed; and
- Enhance intelligence operations for force protection.

[30] As defined in the 1996 Public Law 104-293, *transnational threats* comprise any transnational activity that threatens the national security of the United States – including international terrorism, narcotics trafficking, the proliferation of weapons of mass destruction and the delivery systems for such weapons, and organized crime – or any individual or group that engages in any such activity.

[31] The principal directive providing guidance in this area is DoDD 2000.12, *DoD Combating Terrorism Program*, September 15, 1996.

Force protection, as defined in Joint Publication 1-02, is a DoD security program to protect soldiers, civilian employees, family members, facilities, and equipment in *all locations and situations*. Force and infrastructure protection is accomplished through planned and integrated applications designed to combat transnational terrorism, to enhance physical security, and to upgrade operations security and personnel protective services employing intelligence and counter intelligence as well as other security programs.

The motives and methods of the transnational threat (as evidenced most recently by the coordinated attacks on the US Embassies in Kenya and Tanzania) are vastly different from those of the traditional nation state. The technology of today, and that which is emerging, allows a small number of people to threaten others with consequences heretofore achievable only by nation states. The US homeland, its allies, and interests are vulnerable and continue to be threatened, more so today than in the past. As part of its global responsibilities, the United States is frequently called upon to respond to international crises and to deploy forces around the world. America's position in the world invites attack simply because of its presence. Historical data shows a strong correlation between US involvement in international conflicts and an increase in transnational terrorist attacks against US personnel, facilities, and interests.

At the same time, US military operations will be subject to a growing list of vulnerabilities. All phases of combat operations, mobilization, logistics, command and control, engagement, and clean-up will become more dependent on communication and information systems that are, within themselves, susceptible to terrorist operations. There will be fewer logistic sea and air points of departure and delivery in support of major military operations, which will make these points more attractive targets for terrorist attacks using weapons of mass destruction. Many future operations involving US military forces and infrastructures will be associated with urban operations and will require contact with host populations – conditions at odds with today's preferred protection practices.

Chemical and biological warfare agents share characteristics that make them an especially grave threat. They are relatively easy to obtain, can be developed and produced with modest facilities and equipment, can be extremely lethal even in small quantities, and can be delivered by a variety of means. But chemical and biological materials also have substantial differences. The most important difference, perhaps, is that biological agents can be far more toxic by several orders of magnitude than chemical warfare agents. Thus the range of effects of a few kilograms of a chemical agent could extend several city blocks. By contrast, the same amount of a biological agent could threaten an entire city and its surrounding countryside. A second significant difference is that generally the effects of chemical warfare agents occur much more rapidly – minutes to hours versus days for biological agents. These differences should be taken into account when devising strategies and postures to deal with the transnational threat environment.[32]

It is also important to remain mindful of the nuclear and radiological threat during the planning stages for force and infrastructure protection. If the required fissile material is available, it is not difficult to design and build a primitive nuclear explosive device. The diffusion of

[32] Annex O describes this challenge in *Security of Office Buildings, Embassies, and Other Facilities Against Chemical or Biological Attack.*

knowledge and technology over the past decades makes such a task increasingly possible and a nuclear device can be made small and light enough to be transported to an intended detonation point by a variety of readily available means.

In the United States, the US military can respond, as necessary, to defend personnel or facilities. Outside national borders, the ability of US military personnel to use protective force is far more restricted. US forces are heavily dependent abroad on the capabilities of local police or host nation military for security at the point where local jurisdiction is established. Policies for arming deployed US forces varies from country to country, and site to site, and are dependent upon national sovereignty, legal jurisdiction, and policies of the host nation installation commander. In general, US security forces are limited in their authority to detain suspicious individuals and to use deadly force outside of base perimeters.

Generally, US forces have no jurisdiction beyond the perimeter in overseas locations. Also, with few exceptions, the US Chief of Mission, typically the Ambassador, is responsible for the security of Americans who are not under the direct command of the regional combatant commander. Ongoing actions between the Departments of Defense and State seek to establish a formal memorandum of understanding that would permit the regional commander or the Chief of Mission to negotiate which organization can best provide for the force protection of US forces and personnel.

In both the continental United States and abroad, there are common problems created by encroachment of civilian facilities around military installations: the draw-down of US military medical capabilities and what can be considered an over-reliance on civilian mass casualty medical treatment; and the vulnerability and lack of redundancy in supporting infrastructure such as water and electric utilities.

Another element in the force protection environment is the parallelism between force protection and civil protection. There is a strong synergy between the demands of force projection, force protection, and civil protection. A robust force protection capability is critical to meeting US security needs and maintaining the nation's ability to project its forces abroad. Force protection is part of full-dimensional protection for US forces, extending to family members, civilian employees and facilities, as well as installations, ports, and airfields in both the United States and overseas.

When closely examined, the requirements for protecting military facilities against attacks by transnational adversaries have much in common with protecting civilian facilities and people in metropolitan areas. This mission synergy allows the United States to leverage DoD capabilities and expertise for force protection as it may apply to civil protection. There is a vast experience base in the civilian community among first responders – the firefighters, emergency medical personnel, and law enforcement officers who are first on the scene in the event of a crisis. And the existing resources and experience in DoD to cope with the battlefield use of weapons of mass destruction provide another experience base from which to draw. Both the Department of Defense and the civilian communities can benefit from this synergism by leveraging capabilities and expertise across both mission requirements.

OPERATIONAL AND TECHNOLOGY ENABLERS

Five enablers to achieving full dimensional protection are: mission responsibilities, vulnerability assessments, organization expedients, technology and training initiatives, and intelligence operations.

Assigning mission responsibilities involves integrating force and infrastructure protection into operational and contingency plans for every operational mission. There needs to be an end-to-end mission orientation that describes in detail the elements of deterrence, mitigation, and response to be expected during both peacetime and conflict. Equally important is assigning responsibilities for interrelating with host country civil response and paramilitary forces to remain sensitive to their requirements while providing effective force and infrastructure protection.

Comprehensive vulnerability assessments, employing historical as well as near-real-time transnational threat evaluations, are now a necessity. It is no longer a "nice to have" activity that has in the past been relegated to the "to hard to do" pile. New and compelling rationale mandate a revised and significant improvement in the all-source intelligence processes by which US military force commanders are provided relevant vulnerability and threat assessment information. Future vulnerability assessments should address a full range of disciplines and functional activities and provide: people profiles, transnational terrorism leadership/sponsorship insights, transnational organizations, terrorist missions, available infrastructure/resource assessments, lines of communication, hostile intent, likely targets, and, though not all-inclusive, target vulnerabilities as perceived by a potential protagonist.

Organization expedients for dealing with force and infrastructure protection involve: clarifying command and organizational responsibilities; elevating force protection within DoD's strategy and guidance development processes; redefining force protection as a "major mission component" while recognizing that its programs cut across several funding and programmatic functional areas of responsibility; strengthening the development and advocacy processes; and establishing both the business case as well as the investment strategy(s) to accomplish what needs to be done.

Technology and training is an important enabler and continued focus on applying emerging technologies to force protection is key. There are many technologies, including commercial off-the-shelf technologies, which will aid in achieving full-dimensional protection. A joint force protection test bed can be a focal point for transitioning relevant technologies in support of force protection requirements. In addition, a five-year technology insertion plan, following the precepts already set forth in DoD's "Defense Science and Technology Strategic Plan," needs to be developed and implemented. This plan should take into account not only traditional active and passive/offensive and defensive military means, but also non-traditional methods and means such as extensive use of non-lethals and unconventional technologies to counter and defeat transnational terrorist activities. Such technologies, once deployed, should be capable of being tailored to the appropriate environment in which their use is anticipated – there is no single solution or "silver bullet" to containing the transnational threat.

Force and infrastructure training and education at all levels within DoD component programs needs to become mandatory. While technology is a necessary enabler, it is no substitute for extensive training, proper equipping, realistic exercising, and no-notice readiness evaluations.

Such programs should focus increased attention not only on the means and methods employed by transnational terrorists and terrorist organizations but also on doctrine, procedures, and techniques to counter and/or defeat weapons of mass destruction.

Intelligence support plays an important role in effective force and infrastructure protection. To enhance intelligence operations in support of force protection, the 1997 DSB task force made the following suggestions:

- Sharply increase focus on force protection intelligence needs – they are different;
- Reorient, improve, and accelerate tactical collection, analysis, and all-source fusion programs;
- Upgrade covert capabilities and tools;
- Increase human intelligence and counterintelligence allocation trained to combat transnational threats and especially include coalition partner nations;
- Broaden access to national and international databases including law enforcement and commercial;
- Stop erosion of intelligence resources – reallocate and refocus; and
- Ensure availability of tactical intelligence capabilities.

There is an ever-increasing role and responsibility for the intelligence community in force and infrastructure protection. Thus, the intelligence community should consider ways and means to focus resources specifically on force protection, not to the exclusion of other high-priority missions, but well above the present level of priority today. Local level intelligence correlation and information dissemination management should become routine. There is also a need for local level indications and warning networks involving multi-agency resources. In overseas environments, interagency coordination, real-time information exchange – coupled with appropriate alarming mechanisms – is rapidly becoming a necessity.

Increased human intelligence resources and associated counter-intelligence activities are considered vital. Forces, prior to deploying, during deployment, and upon arrival for mission execution, need to have access to a wide array of national level intelligence information provided in an informational framework that matches force training, education, and exercise experiences. Specific relational databases should be established so that forces and interagency personnel can have ready access to focused information in support of force protection. The force protection mission and its associated responsibilities necessitates a robust, dynamic, responsive infosphere into which any commander or decision maker can obtain up-to-date information on the threat(s) to personnel, facilities, infrastructure, and logistic resources and, quite possibly in the future, computational decision options for command action consideration.

Since Khobar Towers, DoD has taken many steps to improve its force protection posture. While these have been solid efforts, a long-term, sustained campaign plan needs to be developed and executed to achieve full-dimensional protection for US forces – in or out of combat. ***The 1998 Summer Study endorses the recommendations posed by the 1997 Summer Study task force as summarized below:***

- ***Reemphasize force protection as a mission responsibility.*** Force protection needs to be part of day-to-day operational missions worldwide, not just a wartime issue. An end-to-end focus should expand force protection to include capabilities for deterrence, detection, and prevention in addition to mitigation and response. The Secretary of Defense should reemphasize force protection as a mission responsibility by elevating its priority in departmental strategy, guidance, and investment and by making force protection a readiness issue. Improving force protection capabilities should also capitalize on the synergy between this DoD mission and civil protection, to the benefit of both.

- ***Expand scope and breadth of vulnerability assessments.*** The vulnerability assessments being conducted by J-34, the Services, Defense Agencies, and the CINCs provide a useful initiative for evaluating the status of force protection measures throughout DoD. The task force supports the continuation of these assessments but believes that they should be expanded to address a broader range of threats and targets. Thus far, the vulnerability assessments have focused primarily on protecting people, but should be expanded to include mission-related targets, essential infrastructure, and lines of communication. The assessments have emphasized ways to mitigate the effects of high explosives, but should be expanded to provide more attention to addressing the chemical, biological, radiological, and even nuclear transnational threats.

- ***Patch the "seams" created by diverse responsibilities.*** Force protection responsibilities span many organizations and offices in the Office of the Secretary of Defense, the Joint Staff, and the Services. The task force is concerned about the many organizational and functional gaps and overlaps that exist as a result of these diverse responsibilities and their impact in the crucial areas of budget, policy, plans, and programs. The DSB recommends that the Secretary of Defense clarify force protection responsibilities within the Office of the Secretary of Defense, that the Chairman do likewise within the Joint Staff, and that the Services review existing assignments of responsibilities.

- ***Exploit promising technologies.*** The Department of Defense could better exploit current and emerging technologies to reduce force protection vulnerabilities. There are a substantial number of technologies that can be employed to enhance force protection capabilities both in the near term using commercial, off-the-shelf products, and in the long term as various new technologies mature. To ensure that the Department exploits these technologies where they add the most value for the dollars invested, the task force recommends the creation of an enduring test bed capability to help facilitate the transition of technology in support of force protection requirements.

In addition to the test bed, the panel recommends establishing a five-year technology investment plan for rapid technology insertion.

- ***Enhance intelligence operations for force protection***. DoD needs to sharply increase its focus on force protection intelligence needs, particularly at the tactical level. Intelligence collection and analysis remain focused on supporting major theater warfare, but the organization, methodology, and practices that support operational plans do not fully support force protection requirements. There is a need to reorient, improve, and accelerate tactical collection, analysis, and all-source information fusion programs to include coalition partner assets. Additional human intelligence assets are needed – which are crucial elements in understanding the transnational threat. Intelligence analysts need access to a broader set of national and international databases. Finally, the task force urges the deployment of tactical intelligence capabilities organic to local units overseas.

A premier force protection capability will require continuous improvements in response to the changing strategic landscape. These recommendations will go a long way toward making US force protection capabilities sufficiently robust for dealing with the transnational threat.

Theater Ballistic and Cruise Missile Defense

With proliferation of short, medium, and now long-range theater ballistic missiles, and the availability of relatively inexpensive land and sea attack short-to-medium range cruise missiles, the United States faces a threat capable of disrupting military operations, causing unacceptable casualties, and threatening US coalition partners. The US strategy to deal with this threat should be one of defense-in-depth, encompassing elements of prevention, deterrence, and attack operations – against infrastructure and missiles in motion, hide or firing positions – including both passive and active defense. Active defense against ballistic missiles should be multi-layered, including boost phase as well as ascent, mid-course, and terminal phase intercept capabilities. Similarly, effective defenses against cruise missiles would include both wide area and terminal defenders.

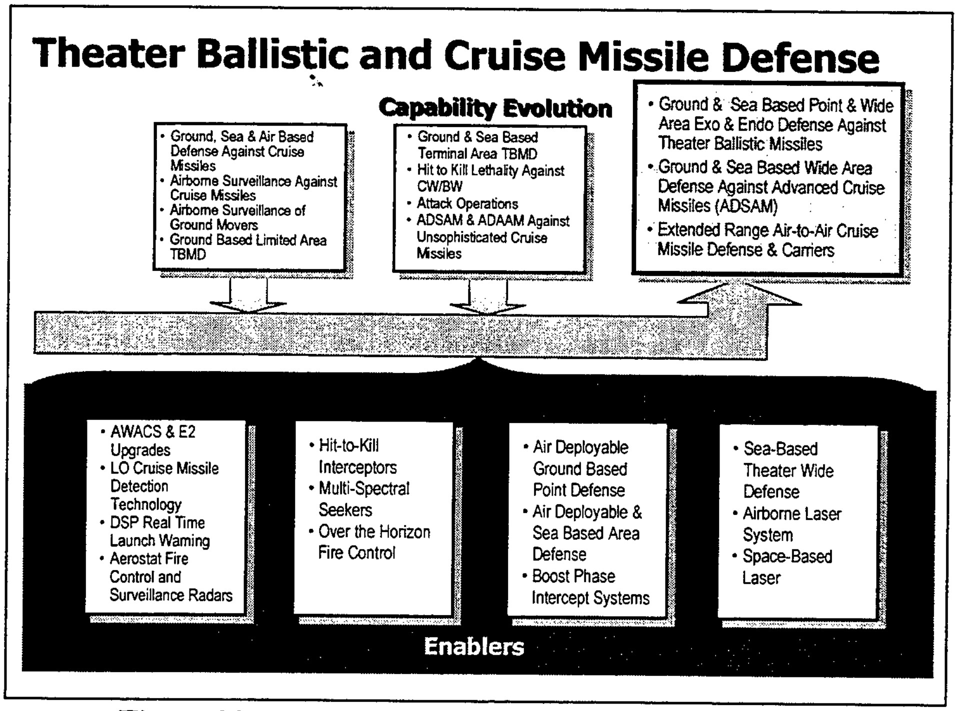

Figure 30. Theater Ballistic and Cruise Missile Defense

The capability evolution and the primary enablers for US defense against theater ballistic and cruise missile systems is shown in Figure 30. The evolving capability goals are noted in the box on the upper right of the figure. Achieving these capabilities will require an integrated combination of networked sensor systems including space-based, infrared systems (SBIRS) such as SBIRS-High/Low, signal intelligence, and surface and airborne radar systems. The DoD has a wide array of missile defense programs and airborne sensor upgrade programs underway. While these systems offer the potential to provide the base for effective missile defenses, formidable technical challenges remain – none bigger than developing and fielding systems with hit-to-kill ballistic missile defense technology.

SENSOR INTEGRATION AND BALLISTIC MISSILE COMMAND, CONTROL AND COMMUNICATIONS (BMC³)

One immediate initiative is to create an interoperable family of sensor systems by "netting" currently available defensive sensor, battle management, and fire control sensor systems. These include the US Marine Corps TP-59, the Patriot and AEGIS assets, the US Air Force TPS-117, and airborne [E-2C, Joint Surveillance and Target Attack Radar System (JSTARS), Airborne Warning and Control System (AWACS)] and space-based sensors such as digital signal processor.

The Joint Composite Tracking Network (JCTN), currently in early concept development, is an approach that allows use of the netted information for early warning, queuing of other sensors and weapons, and fire control. It would provide a Single Integrated Air Picture (SIAP) and builds on JTIDS (Link 16) and CEC developments. The JCTN capability needs to be able to authenticate and correlate multi-sensor inputs to derive desired fire control quality track data. Development efforts need to be multi-Service. The companion BMC^3 system should be capable of controlling not only ground and at-sea missile defenses but integrated air operations as well.

The future BMC^3 system will need to be coupled with national (overhead) and international (coalition partners) assets, and use, to the maximum degree possible, commercial technology and open systems architecture. To do so, DoD will need to solve the security and access problem, in a flexible way, to include coalition defense participation. Additional HAE UAV (Global Hawk-type) and long duration elevated sensors – such as the Joint Land Attack Cruise Missile Defense Elevated Netted Sensor System (JLENS) – will be needed for cruise missile defense.

DEALING WITH WEAPONS OF MASS DESTRUCTION (WMD) MISSILE ATTACKS

Reliable destruction of cruise and ballistic missiles armed with nuclear, chemical, or biological warheads remains a key unresolved challenge. This challenge is made much more difficult if the missile attacker has broken the chemical or biological warfare payload into small, separate bomblets or canister reentry vehicles which may be ejected from a ballistic missile at high altitudes or perhaps even during the ascent phase of its trajectory. These fractionated payloads can be thought of as the theater ballistic missile equivalent to multiple independently targetable reentry vehicle (MIRV) technology found today on nuclear armed SLBMs and intercontinental ballistic missiles (ICBMs). In the case of chemical warfare and particularly biological warfare warheads, they do not need to be highly accurate because of the large lethal areas of these weapons. In fact, MIRVing chemical and biological warfare payloads in some cases may be the preferred means of delivering the agents over a wider area than a single warhead of equivalent agent volume and weight.

Defending against fractionated ballistic missile payloads is an extremely difficult challenge. Long-range (hundreds of miles reach), high-energy laser or kinetic energy boost phase intercept systems could be a first layer of active defense. Even if the US theater ballistic missile defense interceptors could successfully engage and destroy a canister/reentry vehicle, the defense would be overwhelmed by the number of re-entry vehicles to engage and would rapidly exhaust its

interceptor inventory. Also, the defense would be faced with unfavorable cost exchange ratios: the cost per intercept is close to $1.0 million per shot while the attacker's cost for the whole missile and fractionated payload is considerably less. The same tactics of payload fractionation could be employed on cruise missiles flying at high altitudes or using pop-up maneuvers near the target area.

For these reasons, the DSB recommends that DoD increase the effort to define and develop boost phase intercept systems to include considering hypersonic kinetic energy kill systems to complement airborne laser and space-based laser approaches.

MISSILE DEFENSE SYSTEM INTEGRATION

DoD needs to integrate all development programs for theater ballistic and cruise missile defense into the most effective system-of-systems possible, in order to maximize the impact of individual systems. Such a system might integrate Theater High Altitude Air Defense (THAAD), Patriot, PAC 3, Navy Area, Navy Theater Wide, Medium Extended Air Defense System (MEADS) and Airborne Laser (ABL) supported by a variety of integrated sensors. A system-of-systems approach needs theater-wide coordination to maximize the kill probability and minimize interceptor wastage.

The recently published Rumsfeld Commission Report concluded "...The newer ballistic missile-equipped nations...would be able to inflict major destruction on the United States within about five years of a decision to acquire such a capability." America should assume that Iran, as a minimum, will have the capability to reach all of Europe by the time the United States deploys THAAD and Navy Theater Wide sometime between 2005-2010. Considering the May 1998 testing of the Shahab-3, it will be a race against time to get THAAD and Navy Theater Wide deployed before the Shahab-3 and the longer-range Shahab-4 are operationally deployed. Also considering "Iran is placing extraordinary emphasis on its ballistic missile and WMD development programs," as stated by the Rumsfeld Commission, DoD needs to ensure that US interceptors have sufficient lethality against WMD warheads. Significant challenges are early release submunitions, pen aids, and missile fragmentation to create decoys. The US theater ballistic missile defense program capabilities have been running behind the threat from the beginning and should be accelerated as much as technically feasible.

Defense against long-range rockets, such as those possessed in great numbers by North Korea, and short-range missiles of less than about 100km have not been addressed in DoD's theater ballistic missile defense (TBMD) programs.

The Services have established programs addressing the DARPA sensors related to AWACS, JSTARS, and JLENS. Although the AWACS and JSTARS programs appear to be proceeding satisfactorily, the JLENS program has run into both management and funding problems. JLENS has received serious Congressional and Army budget cuts and is in jeopardy without increased OSD, Joint Staff, and Army support.

The responsibility for creating a Joint Air Defense Architecture was given to JTAMDO which was created in 1997 under the auspices of J-8. The Ballistic Missile Defense Organization (BMDO) was given the responsibility of performing the systems engineering. JTAMDO has promulgated a Joint Operational Air Defense Architecture, which is working its way through the

Pentagon. BMDO is in the beginning stages of working on systems engineering for the Joint Architecture. JTAMDO has gotten off to a good start, but needs strong support from OSD, the Joint Staff, and the Services to be successful.

An effective cruise missile defense depends upon the system integration of airborne long-range sensors, the SIAP, Combat Identification (CID), CEC, and the concepts of Air Directed Surface-to-Air Missile (ADSAM) and Air Directed Air to Air Missile (ADAAM). Also needed are highly capable interceptors to handle the high-end threat and low-cost interceptors to handle the thousands of low-cost missiles the Third World could build for an expected cost of $150,000 each or less. Although US capability toward a SIAP has improved to some extent since Desert Storm with the fielding of Link 16, it is far from adequate. CID capability, which is necessary for an effective anti-air warfare system as well as to prevent fratricide, has improved little since Desert Storm and is one of DoD's weakest links in the Joint Air Defense Architecture. The 1994 DSB Report "*Cruise Missile Defense*" recommended that the Air Force and Army study how CEC could help in their cruise missile defense programs. Although some studies have been conducted, efforts to incorporate CEC into their related programs have been slow. ADSAM and ADAAM are concepts with great potential but are inadequately funded to develop within the time frame of the expected threat.

The investment to design and build interceptors effective against land attack cruise missiles is also inadequate. Since the best "Poor Man's Air Force" is thousands of land attack cruise missiles, the DoD needs a low-cost interceptor to counter the quantities of possible threats. Since cruise missiles are an effective means of delivering chemical and biological weapon attacks, the theater cruise missile defense system needs to be able to defeat attacks from cruise missiles carrying weapons of mass destruction. An effective theater cruise missile defense system needs to have the capability to destroy chemical or biological warfare agent payloads well away from the intended target to minimize contamination.

The perception of the threat has an impact on the priority given to building a timely and effective theater cruise missile defense system. The DSB task force urges the department to continue to give high priority to the threat from theater and cruise missiles.

RECOMMENDATIONS

To defend against the threat of theater ballistic and cruise missiles, the DSB task force recommends that:

- The Secretary of Defense appoint a commission similar to the Rumsfeld Commission to assess the cruise missile threat to US deployed forces and coalition partners;
- The intelligence community be tasked to review their methods of assessing land attack cruise missile threats in light of today's pattern of weapon system development in developing nations;
- The Under Secretary of Defense for Acquisition and Technology and the Chairman, Joint Chiefs of Staff should increase the priority of theater and cruise missile defense and ensure continued support for JTAMDO. One program that should receive special attention to ensure adequate resources is JLENS;

- The Department provide tasking and support to BMDO to develop an integrated joint resource BMC^3 capability that would include coalition partners;
- DoD initiate a program to develop long-range standoff kinetic energy kill boost phase intercept systems;
- BMDO be tasked to develop lethality options other than hit-to-kill interceptor warheads which produce neutralizing thermal effects on biological and chemical weapon fractionated or unitary reentry vehicles at affordable costs;
- DoD address the Long Range Rockets and Short Range Missiles < 100km threat in the Theater Ballistic Missile Defense Architecture and Acquisition programs; and
- Continuous support for MEADS for mobile air and cruise missile defense in littoral operations.

Urban Operations

We declare that only fools fight in cities and shut our eyes against the future. But in the next century, in an uncontrollably urbanizing world, we will not be able to avoid urban deployments short of war and even full-scale city combat. Cities have always been centers of gravity, but they are now more magnetic than ever before... They are also the post-modern equivalent of jungles and mountains—citadels of the dispossessed and irreconcilable. A military unprepared for urban operations across a broad spectrum is unprepared for tomorrow.

RALPH PETERS, OUR SOLDIERS, THEIR CITIES

Urban areas have proven to be a locus for US military intervention in the post cold war period. American forces have conducted major operations in Panama City, Port-Au-Prince, and Mogadishu, and noncombatant evacuation operations in Tirana, Kinshasa, Monrovia, and Freetown. The tide of expanding urbanization in the developing world has increased the likelihood that US forces will again be called upon to operate in urban areas.[33] The evolution of urban warfare capabilities, as shown in Figure 31, and the associated enabling technologies – in the five areas of knowledge, maneuver, fires, autonomous systems, and logistics – address the challenges posed by urban warfare.[34] Future urban warfare capabilities will explore the tenets of maneuver warfare in an environment that has traditionally been characterized by attrition-style combat. By combining this new approach with emerging technology, US forces will exploit the unique characteristics of urban settings. This urban warfare discussion should help guide the process of research and experimentation by which DoD will discern required operational capabilities and potential solutions.

THE CHALLENGE

The demands of warfare in an urban environment are especially challenging. Urban terrain is an extraordinarily intricate blend of horizontal, vertical, interior, and exterior forms superimposed upon the landscape's natural relief, drainage, and vegetation. The average city includes many styles of construction using a multitude of different building materials, each with its own texture and strength. As cities become physically larger and more populous, urban terrain grows more complex. Buildings increase in number, as well as in size. Road networks become more extensive, to include heavy-duty, multi-lane highway systems. Subterranean infrastructure expands as subways, utility tunnels, and storm sewers reach out to service broader areas.

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[33] According to United Nations estimates, the urban population of developing countries worldwide increases by about 150,000 people each day, with the most pronounced growth occurring in Africa and Asia. By the year 2025, three-fifths of the world's population – five billion people – will live in urban areas.

[34] The five enablers for urban warfare are discussed individually in Volume II.

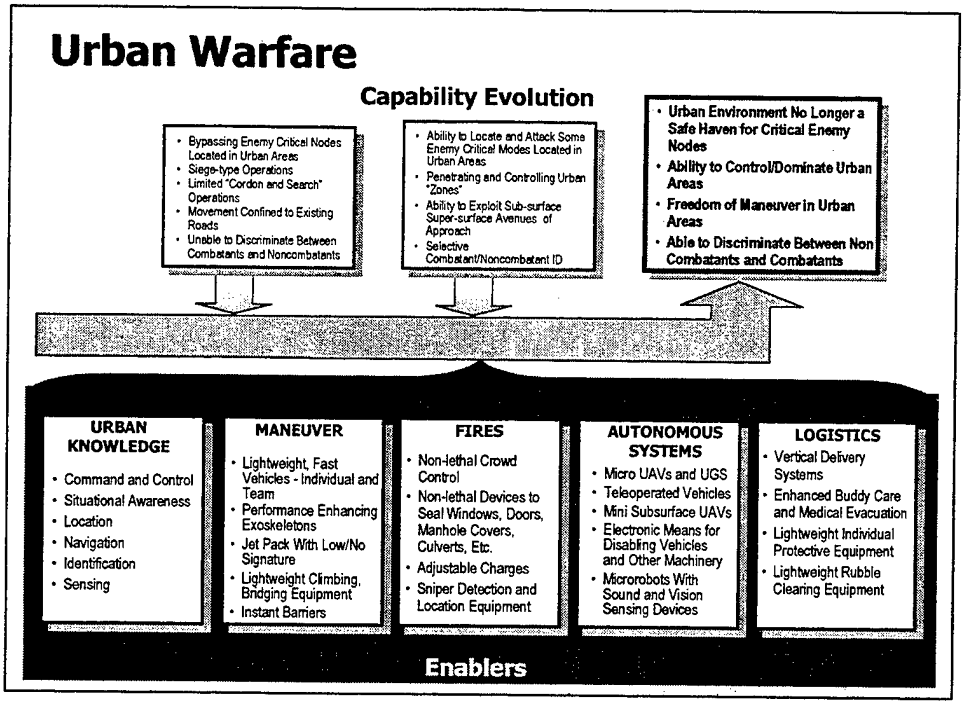

Figure 31. Urban Warfare

Urban terrain influences the conduct of military operations and weapons options to a greater degree than does any other terrain type. Unique to military operations in urban terrain is that the conduct of operations can radically alter the physical nature of the terrain in ways and to an extent not experienced in other environments. Some buildings suffer damage, with collapsed walls or roofs, while others are razed completely, leaving only a pile of rubble. These effects can be militarily significant, as some key terrain features disappear altogether and fields of fire open and close.

Urban terrain is highly restrictive, limiting observation distances, engagement ranges, weapons effectiveness, and mobility. These factors tend to force extremely close combat with troops fighting from building to building and from room to room. Command and control is difficult because small unit leaders cannot see their troops, and radio communication is subject to interference caused by the presence of structures. Historically, urban combat has called for a high degree of initiative by small unit leaders operating with near-autonomy.

In the future, the urban environment will present US and coalition partner forces with situations requiring the conduct of many different categories of military activities. Humanitarian assistance operations, peace operations, and full-scale, high-intensity combat may occur simultaneously in different neighborhoods. Integrating and coordinating these varying evolutions, each of which has its own peculiarities, will challenge American forces to use their skill and determination in innovative and imaginative ways. The presence of large numbers of noncombatants and the potential difficulty in distinguishing these noncombatants from hostile forces will further complicate the task of operating in the urban environment.

Historically, operational tacticians have viewed military operations in urban terrain as attrition-style warfare, which is characterized by the application of firepower to achieve the cumulative destruction of the enemy's materiel assets. The extreme granularity of urban terrain has limited conventional mobility and tended to "absorb" relatively large numbers of personnel. Unit frontages have been dramatically diminished, with advances or withdrawals measured in terms of single buildings or blocks. Troops expended extraordinary quantities of ammunition in efforts to use firepower to destroy enemy forces protected by the cover of structures and rubble. Attackers systematically bludgeoned their way from building to building, while their opponents doggedly defended every cellar and room. Fierce and continuous close combat resulted in great material destruction, property damage, and high casualties among combatants and noncombatants alike.

Such attrition-style combat can exact a toll in casualties and destruction, which is inconsistent with both America's system of values and philosophy of warfare. Thus DoD's concept for operations in urban terrain needs to evolve beyond attrition-style warfare. In the future, US forces need to develop methods to leverage the peculiarities of the urban environment to develop and maintain tempo, thereby creating a cascading, deteriorating effect upon the enemy. This will require new ways of thinking about operations in cities, as well as exploring new technologies to facilitate the conduct of maneuver warfare in urban conditions. US forces need the technical capability and the operational acumen to identify the enemy's positions of strength and critical vulnerabilities in the urban setting. US forces need to rapidly maneuver through built-up areas, using new and unorthodox mobility techniques to avoid surfaces and exploit gaps. They will bypass and isolate the enemy's centers of resistance, striking killing blows against those enemy units, positions, or facilities upon which his force depends. In the defense, instead of focusing efforts on creating of heavily defended strong points, American and coalition forces will drive the enemy into killing zones, and then use enhanced mobility and overwhelming firepower to deliver counterattacks which will unhinge enemy plans.

ENHANCING OPERATIONAL CAPABILITIES

Command and Control. It is important for communication devices to function in multi-dimensional urban surroundings, ensuring reliable communications between structures, streets, and sewers. Command and control systems need to provide commanders with a mechanism for identifying urban features and expressing plans to subordinates in three-dimensional terms. US and coalition forces need to be able to determine and report locations in three-dimensional terms as well, with sufficient precision to identify individual rooms in a building, or even specific locations within rooms. Command and control mechanisms should display three-dimensional terrain in formats that enhance understanding and provide the user a "feel" for the ground. Computer-generated map products will provide a graphic representation of urban terrain, reflecting in near-real time changes caused by combat action, such as collapsed structures or flooded subways. Such products will be data-intensive; command and control hardware needs to be capable of retrieving, exchanging, storing, displaying, and manipulating these data in large quantities and at a very-small unit level. Commander's intent, mission tactics, and implicit communications will remain fundamental to applying maneuver warfare to the urban

environment. It is important that command and control procedures and systems be flexible and adaptive to account for the uncertainty inherent in combat.

Mobility/Countermobility. The freedom to conduct movement within and between urban facilities will be critical to US efforts to adapt maneuver warfare to the urban environment. US forces will need enhanced mobility characteristics to facilitate:

- Rapid breaching of steel-reinforced concrete walls;
- Vertical movement inside structures without the use of existing staircases;
- Vertical movement on the outside of structures;
- Horizontal movement between structures above ground level; and
- Penetration of pavement and building foundations for movement between surface and sub-surface zones.

Units moving in or between urban zones need to be able to navigate effectively, and to coordinate their activities with units in other zones, as well as with units moving outside the city. Thus, navigation and coordination capabilities need to be resident at the very-small-unit level, perhaps even with each member of a unit.

American and coalition forces will conduct countermobility evolutions to limit or deny the enemy's freedom to maneuver along urban avenues of approach, which might include streets, subways, or passages through buildings. In an attack, when units bypass enemy centers of resistance, they will use countermobility means to contain the enemy and to seal potential avenues of approach which might facilitate enemy counterattacks. In the defense, countermobility systems and procedures will form an integral part of the overall plan, limiting the enemy's maneuver options and channeling him into killing zones.

Measured Firepower. Future urban warfare will call for "measured firepower." Structures and rubble will provide increased cover, requiring greater firepower to achieve desired effects against the enemy. At the same time, the potential presence of noncombatants will simultaneously demand reduced lethality in weapons employment. Measured firepower can enable forces to deny the enemy the protection from the urban environment. American and coalition forces need the flexibility to attack targets located within buildings or rubble, and to conduct engagements from surface to sub-surface, and vice versa. Measured firepower needs to provide reasonable certainty of achieving the desired effect on the enemy, but with reduced risk of injury to noncombatants. In some situations, for example, forces might be required to "implode" large buildings defended by the enemy, without seriously damaging surrounding structures. In other situations, they might employ nonlethal weapons to clear structures shared by enemy forces and noncombatants.

The nature of urban terrain will present challenges in employing fires. Limited visibility will affect targeting, fire support coordination, and battle damage assessment. Tall structures will become intervening crests for surface-delivered fires. The cover afforded by the terrain will affect penetration characteristics and fuze functioning, reducing weapons effects below the threshold for successful engagement. The fire support system should be able to adapt to these conditions by providing target location and designation in three-dimensional terms, precise

ordnance delivery (to a specific room in a building, for example), munitions with variable penetration and explosive characteristics, and coordination of lethal and nonlethal fires against different targets near one another. It is important for forces to fully understand the expected effects of ammunition when used against different combinations of building materials. The capability to call for and adjust supporting arms in an urban environment needs to be resident at the very-small-unit level, perhaps the squad, and US and coalition forces at every level need to understand the integration of fire and maneuver in urban terrain.

Survivability. Urban combat has historically resulted in high casualties, particularly among units attempting to maneuver through streets forming narrow and exposed avenues of approach, against enemy units entrenched in the rugged terrain of the city. Future forces will use force protection measures adapted for future military operations in urban terrain to facilitate maneuver with reduced risk of casualties. Individual and collective protection might serve to lower the incidence of some types of casualties.

Protective measures required for future military operations in urban terrain will include special medical capabilities. Individuals will be exposed to a wide variety of infectious diseases that breed in the close and heavily populated environment of a city. The nature of the terrain will result in a greater number of accidental injuries than are normally encountered in other operating environments: troops will fall from heights, they will suffer cuts from glass and other sharp objects, and they will be hit by falling debris. Troops might be wounded while in locations from which it is difficult to evacuate: a flooded subway or sewer, a major intersection swept by enemy fire, or the 30th floor of a 40-story building in which the enemy holds many upper and lower floors. Systems need to be in place to provide for prompt and effective care of the wounded under such challenging circumstances.

Adaptability. To adapt to urban terrain, future forces will have to employ economy of force, operating in ways that will reduce the tendency of urban terrain to absorb manpower. Task-organized combat formations can facilitate the adaptability required. Forces operating in a city should be trained, organized, and equipped in such a manner as to facilitate smooth and rapid transition from one task organization to another. This characteristic will help to control the tempo of operations and maintain the initiative. While task organization is a standard practice, it needs to be carried to the very-small-unit level when applying maneuver warfare in an urban battlespace. Platoon commanders and squad leaders exercising initiative in pressing the battle against the enemy might find their units separated from adjacent units or higher headquarters. It is important that small-unit leaders be capable of planning and executing independent operations involving employment of special capabilities, as well as integrating supporting arms. All units need to be capable of readily disassembling into a number of independently functioning component parts and reassembling again, without losing momentum. Most important, adaptability calls for the capacity to rapidly change the organization and capabilities of any unit to gain maximum advantage as the situation ebbs and flows.

Awareness. Urban terrain will provide superb concealment for units occupying or moving through structures, subways, sewers, alleys, or narrow streets. Not only will this characteristic increase the difficulty of detecting the enemy, but it will also render command and control efforts more challenging by screening friendly units from their commanders' observation. "Awareness" is the ability of an individual or a unit to sense the battlespace and to accurately assess information regarding the terrain and the presence of friendly, enemy, and noncombatant

personnel. Enhanced awareness will allow future forces in a built-up area to gather information despite the presence of masking terrain features.

A particularly challenging aspect of urban terrain is the fact that much of the "volume" of a major city is actually interior – the space found inside structures or under the ground. Forces need the capability to "sense through walls" and to externally detect the presence and shape of tunnels and sewers with remote sensors. Sensors should provide for three-dimensional interior rendering, with the capability to display, store, and transfer information between units. For example, a patrol operating at surface level should be able to identify and report the extent and shape of the subways and sewers running under their patrol route at the sub-surface level. Other systems should provide a capability for remote interior sensing, perhaps using equipment mounted on aircraft of the aviation combat element. This also suggests that there is a massive data collection initiative that could develop detailed city maps, sewer and utility tunnel locations, subways, utility layouts, and other relevant data. The Army and Marine Corps might want to explore this urban data problem with the National Imagery and Mapping Agency (NIMA).

Sustainability. In future urban operations, it is essential that the logistics system adapt to the characteristics of the environment to enhance tempo and sustainability. The two distinguishing features of urban operations – the terrain and the presence of noncombatants – will both impact logistics. At the tactical level, forces will conduct combat service support (CSS) to provide for supply, maintenance, transportation, health services, engineering, and services under the special conditions urban operations. Combat service support organizations need to be able to locate and reach dispersed elements of supported units in "vertical" urban terrain. Functions which occur routinely under field conditions will take on new dimensions in the urban environment: salvage and repair of an armored vehicle in a narrow street, evacuation of wounded troops from the upper portion of a skyscraper, and resupply of units operating in a storm sewer.

In some cases, the urban environment itself might be subject to exploitation for purposes of CSS. Water, fuel, rations, construction materials, and medical supplies might be available, either for use by units or to provide for the needs of noncombatants or enemy prisoners of war. Local facilities and infrastructure that remain reasonably intact could serve the needs for hospitals, vehicle maintenance depots, and communications systems. For example, civilian vehicles and heavy equipment may serve to supplement those of the force. Subject to security considerations and the Laws of Armed Conflict, local residents with special expertise might be able to provide some assistance. The capability to extract resources from the urban environment needs to be built into the CSS system.

FUTURE DIRECTIONS

Mastering urban warfare will not be easy. All of the Services need to examine their doctrine, organization, training and education, equipment, and support systems and be able to adapt these capabilities to the operational and tactical-level requirements for urban warfare. New technologies that will facilitate the conduct of joint maneuver warfare in urban operations need to be explored. Advanced sensing, locating, and data-display systems can help US and coalition forces leverage information to reduce some of the masking effects of built-up terrain. New weapons and ammunition can provide the flexibility to engage enemy forces in urban cover,

while limiting noncombatant casualties and collateral damage. Mobility enhancement devices might assist in negotiating the complex, three-dimensional terrain found in a modern city.

It is important that improving US capabilities for urban operations goes beyond simply adapting new technologies, as asymmetric warfare in urban settings can negate the US technological edge. Cities quickly soak up troops, ammunition, and time. Likewise, dominant battlefield knowledge is masked in a domain typified by chaos, clutter, and confusion. Israel learned these lessons in Beirut; Russia learned these lessons Grozny; America learned them in Vietnam and Mogadishu; and the British continue to learn them in Northern Ireland. The Marine Corps Urban Warrior series of advanced warfighting experiments and the Army/Marine Corps Military Operations in Urban Terrain advanced concept technology demonstration (ACTD) have begun to address some of the urban challenges and reinforced the dilemmas of operating in urban environments. DoD needs to integrate its approach to capabilities for military operations in urban terrain. There is no single solution – technological, doctrinal, or organizational – that will fulfill the requirements for applying maneuver warfare to the urban environment.[35]

The DSB task force supports the Department's efforts addressing the challenge of urban operations – to include the Urban Warrior advanced warfighting experiments and the military operations in urban terrain ACTD – and urges that these activities be embraced throughout the joint Service arena.

[35] The discussion of urban warfare and the capabilities required for urban warfare was based on the US Marine Corps concept paper, *Military Operations on Urbanized Terrain.*

CHAPTER 6.

Recommendations and Implementation

Achieving a capability to apply early and then continuous dominant combat effects across the spectrum of conflict is the most difficult and central of the many operational challenges associated with underwriting Joint Vision 2010. ... the Department of Defense is capable, both technologically and financially, of building a dominant early entry capability.

CHAPTER 6.

Recommendations and Implementation

The task force believes that the central challenge in underwriting Joint Vision 2010 is developing the capability to apply *early and continuous dominant combat effects across the spectrum of conflict.* Achieving this overarching capability requires a number of key operational enabling capabilities described in the preceding chapters: assured knowledge superiority, responsive global targeting, exploiting the littoral battlespace, inter- and intra-theater mobility, coalition warfare, force and infrastructure protection, theater ballistic and cruise missile defense, and urban operations. Meeting these operational challenges, with early combat power at the core, will be essential to an effective next-generation force.

An important element of maintaining US superiority in the 21st century is assured knowledge superiority. There is common agreement that it will not be possible to suppress adversary access to advanced commercial systems. Thus, it is important that the United States continue to out-innovate the competition, and information operations – both offensive and defensive – will be key. While developing these new capabilities, it is important that the United States continue to maintain its current superiority by paying attention to America's asymmetric strengths as well as the asymmetric strengths of potential adversaries.

Future forces will need to operate in an environment of *integrated* operations and logistics – these are closely connected, parallel, inseparable functions of combat. Rapid, agile, and mobile forces require a transformed logistics system that sends less to the field with highly responsive lift. Such integration is possible. In addition, Joint Vision 2010 will make even more demands on the quality of people and more demands on training, as each force element will be required to better exploit new capabilities in more complex situations.

The task force has identified a set of recommendations, in the following tables, that form important building blocks for effective early entry and continuous combat effectiveness. With each recommendation, an implementing organization is identified as well as an estimate of the level of investment required where appropriate. Many of the recommendations have low to modest risk, with potential payoff within the next decade. These recommendations include an integrated information infrastructure, continued progress in chemical and biological warfare defense, advanced munitions, bomber upgrades, Trident conversion, and a family of lightweight vehicles, among others.

Other recommendations focus on development endeavors with longer-term payoff, and in many cases, with higher investment costs. The task force recognizes the significant resource implications of the long-term recommendations. To pay for these new developments, which are vital to underwriting Joint Vision 2010, the DoD needs to reprioritize its research and development and procurement programs from 20th-century hardware to 21st-century needs. In some cases these longer-term initiatives reflect programs that are in some stage of development or definition but deserve more attention and support, such as the expanded MPF-2010, heavy lift HAE UAV systems, and the space operations vehicle. Others are suggestions for future replacement systems, such as the SSTOL and fast shuttle intra-theater sea lift. The task force believes that implementing these recommendations is achievable within the Department's long-range budget plans, but only if there is a major shift in priorities and clear recognition that implementing Joint Vision 2010 and beyond will not be cheap or easy.

RECOMMENDATIONS

Early and Continuous Combat Effectiveness

- Define and establish joint force packages of agile, lethal, survivable early deploying combat forces (*Joint Staff, US Atlantic Command, Services*)
- Develop a family of lightweight, energy-efficient vehicles (*Army/Marine Corps/DARPA, $500 million*)
  - Lightweight armored vehicle
  - General-purpose wheeled vehicle less than half the weight and cube of the High-Mobility Multi-Purpose Wheeled Vehicle (HMMWV) – commercially based
- Program the heavy bomber upgrades to create precision strike platforms (*Air Force, $1 billion*)
  - Small, precision munitions
  - Dynamic mission planning
  - Command and control (C^2) connectivity
  - Forward-based support
- Convert four Trident submarines to high-capacity, precision-strike platforms (*Navy, $1.52 billion*)
- For the longer term, pursue a space operations vehicle and develop common aero vehicle payloads (*Air Force, several billion in 2000-2015*)
- Field the family of advanced munitions in needed numbers (*USD/A&T, $500M-$1B*)
  - Current development programs
  - New advanced munitions

Assured Knowledge Superiority

- Explore – through experiments – command and control structures, processes, and technologies that enable: (*Joint Staff/US Atlantic Command, $30 million annually*)
  - Immediate and continuous operations on the move
  - Dispersed forces and dispersed C^2
  - Shared real-time understanding of situation and commander's intent
  - Synthesize data into knowledge, pushed to and pulled by users
- Develop a single Integrated Information Infrastructure for battlespace awareness, logistics, targeting information, and command and control based on: (*USD/A&T, $1-2 billion*)
  - Exploiting commercial internet technologies and practices
  - Integrating legacy C^4ISR systems
- Protect superiority with enhanced information operations (*Joint Staff/ NSA, $100 million*)

RECOMMENDATIONS

Responsive Global Targeting

- Integrate space-, air-, and surface-based sensors and associated tools for exploitation and management (*ASD/C^3I, $100 million annually*)
  - Focus additional sensor development on continuous coverage and obscured targets (foliage, underground, urban)
- Implement a "common-grid" to register targets, sensors, and weapons with a target location error of less than one meter (*ASD/C^3I, $100 million*)
- Develop effective, dynamic planning tools for: (*Joint Staff/Services/ DARPA, $50 million*)
  - Seamless planning and execution of continuous operations
  - Targeting precision weapons and target allocation
- For the longer term, expand high altitude endurance UAV plans for heavier lift, multi-mission operations (*Air Force*)

Flexible Survivable Intra-Theater Mobility

- For the longer term, expand MPF-2010 to include a ship capable of functioning as an inter-theater airlift base and a highly mobile offshore base, with a 600 foot runway (*Navy*)
- As the eventual C-130 replacement, initiate development of a sea and land-based capable intra-theater SSTOL air lifter (*Air Force/DARPA*)
- Replace current lighterage with a fast shuttle intra-theater sea lift (*Navy*)

Exploiting the Littoral Battlespace

- Maintain commitment to improved mine countermeasure capabilities (*Navy, $438M in FY2000-2005*)

In summary, Joint Vision 2010's focus on achieving dominance across the range of military operations through the application of new operational concepts is a viable template for developing the Department's forces in the coming decades. It is important to emphasize that it is the synergy between the tenets of Joint Vision 2010 – dominant maneuver, precision engagement, focused logistics, and full-dimensional protection, underwritten by information superiority – that will lead to a joint, integrated, dominant capability. Achieving a capability to apply early and then continuous dominant combat effects across the spectrum of conflict is the most difficult and central of the many operational challenges associated with underwriting Joint Vision 2010. The task force believes that the Department of Defense is capable, both technologically and financially, of building a dominant early entry capability that allows for continuous combat power from "the first hours" by obtaining effective operational capabilities in the areas highlighted above.

But implementing the needed mix of initiatives by the Department will be a complex undertaking, exacerbated by the many competing demands for resources. The task force recommends the following overarching tasks to the Department's leadership:

***Secretary of Defense lead implementation by*:**

- Guidance emphasizing creation of forces that achieve early and continuous combat effectiveness
- Directing implementation of specific initiatives

***Chairman, Joint Chiefs of Staff*:**

- Build the needed operational architecture for an early and continuous combat capability
- Validate with a Joint Early Entry Force established for experimentation

Under Secretary of Defense for Acquisition and Technology:

- Prioritize the research and development and procurement accounts to ensure emphasis on these operational challenges

Underwriting Joint Vision 2010 is a significant challenge, but it is within the Department's ability to accomplish. This report has described a context for future force development. At its core is the theme of early and continuous combat effectiveness across the spectrum of conflict. Focusing on this challenging concept should help guide the Department to a superior 21st century military capability, with full spectrum dominance – the central theme of Joint Vision 2010.

ANNEX A:

References of Prior Defense Science Board Studies

REFERENCES OF PRIOR DEFENSE SCIENCE BOARD STUDIES*

Report of the Defense Science Board Summer Study on Simulation, Readiness and Prototyping, January 1993, Unclassified. (DTIC #ADA 266125)

Memo Report of the Defense Science Board on Tactical Aircraft Bottom up Review, July 1993, Unclassified. (DTIC #ADA 274506)

Report of the Defense Science Board 1993 Summer Study Task Force on Global Surveillance, December 1993, Secret. (DTIC #ADC 051840)

Report of the Defense Science Board Task Force on Readiness, June 1994, Unclassified. (DTIC #ADA 286412)

Report of the Defense Science Board 1994 Summer Study Task Force on Information Architecture for the Battlefield, October 1994, Unclassified. (DTIC # ADA 286745)

Report of the Defense Science Board 1994 Summer Study Task Force on Military Operations in Built-up Areas (MOBA), November 1994, Unclassified. (DTIC #ADA 292130)

Report of the Defense Science Board 1995 Summer Study Task Force on Investments for 21st Century Military Superiority, October 1995, Secret. (DTIC #ADC 057361)

Report of the Defense Science Board/Defense Policy Board Task Force on Theater Missile Defense, January 1996, Unclassified. (DTIC #ADA 318537)

Report of the Defense Science Board Task Force on Logistics Modernization, July 1996, Unclassified. (DTIC #ADA 317309)

Report of the Defense Science Board Task Force on Strategic Mobility, August 1996, Unclassified. (DTIC #ADA 316992)

Report of the Defense Science Board 1996 Summer Study Task Force on Tactics and Technologies for 21st Century Military Superiority, Volume I, October 1996, Unclassified. (DTIC #ADA 318788)

Report of the Defense Science Board 1996 Summer Study Task Force on Tactics and Technologies for 21st Century Military Superiority, Volume II, Part 1, Supporting Materials, October 1996, Unclassified. (DTIC #ADA 320508)

* Defense Science Board studies can be ordered through the Defense Technical Information Center (DTIC).

Report of the Defense Science Board 1996 Summer Study Task Force on Tactics and Technologies for 21st Century Military Superiority, Volume III, Technology White Papers, October 1996, Unclassified. (DTIC #ADA 320452)

Report of the Defense Science Board 1996 Summer Study Task Force on Achieving an Innovative Support Structure for 21st Century Military Superiority, November 1996, Unclassified. (DTIC #ADA 320394)

Report of the Defense Science Board Task Force on Information Warfare Defense, November 1996, Unclassified. (DTIC #ADA 319571)

Report of the Defense Science Board Task Force on Command, Control, Communications, Computers, Intelligence, Surveillance and Reconnaissance (C^4ISR) Integration, February 1997, Unclassified. (DTIC # ADA 326142)

Report of the Defense Science Board Task Force on Global Positioning System Phase II, February 1997, FOUO. (DTIC #ADB 226436)

Report of the Defense Science Board 1997 Summer Study Task Force on DoD Responses to Transnational Threats, Volume I, October 1997, Unclassified. (DTIC #ADA 333273)

Report of the Defense Science Board 1997 Summer Study Task Force on DoD Responses to Transnational Threats, Volume II (Force Protection Report), October 1997, Unclassified. (DTIC # ADA 338911)

Report of the Defense Science Board 1997 Summer Study Task Force on DoD Responses to Transnational Threats, Volume III (Supporting Reports), February 1998, Unclassified. (DTIC # ADA 342113)

Report of the Defense Science Board Task Force on Deep Attack Weapons Mix Study (DAWMS), January 1998, Unclassified. (DTIC #ADA 345434)

Report of the Defense Science Board Task Force on Satellite Reconnaissance, January 1998, Unclassified. (DTIC #ADA 341955)

Report of the Defense Science Board Task Force on Underground Facilities, October 1998, SECRET/NOFORN.

ANNEX B:

Cost, Affordability, and Acquisition Strategy Issues

COST, AFFORDABILITY, AND ACQUISITION STRATEGY ISSUES

In the past, Defense Science Board studies rarely have considered the cost and affordability implications of their analysis and recommendations. This omission has denied the full benefit of these studies to Executive Branch and Congressional decision makers faced with the difficult task of allocating constrained defense budget resources among many valid programs and activities.

The participants in this 1998 Summer Study addressed resource considerations in general and recommended ways in which a full analysis of these important factors can be accomplished as the Department of Defense determines how best to implement the recommendations presented in this report.

Considering cost and affordability is consistent with, and supports, the renewed emphasis initiated by the Office of the Secretary of Defense (OSD) on acquisition program affordability both within and beyond the Future Years Defense Program (FYDP). The task force applauds this initiative, which was promulgated in a July 13, 1998, memorandum entitled *"Affordability Assessments of the Defense Acquisition Portfolio,"* signed by the Under Secretary of Defense (Acquisition & Technology) (USD(A&T)) and the Acting Director of the OSD Office of Program Analysis and Evaluation.

Unless a major threat to the security of the United States emerges that is demonstrable to the American public, severe constraints on defense spending are likely to continue for the foreseeable future, despite the fact that the military's operational tempo is significantly greater now than during the Cold War. For example, there has been a plethora of recent reports about serious under funding in the FY 2000-2005 Program Objective Memoranda of the Army, Navy, Air Force, and the Ballistic Missile Defense Organization.

Thus, DSB-recommended efforts will have to compete for funds in an increasingly constrained fiscal environment, and the utility and credibility of any DSB study may rest partly on how well the particular analysis and recommendations address cost and affordability issues.

The 1995 DSB Summer Study, *"Investments for 21st Century Military Superiority,"* contained an initial attempt to identify costs and to advocate an investment plan for its recommended programs and activities. The participants in the 1998 effort believe the Department of Defense should undertake a similar effort for the initiatives recommended this year.

The present effort also may need to identify a broader set of funding sources than those suggested in the 1995 study – reductions in infrastructure, force structure and redundancy in combat-related missions, increased privatization and outsourcing, new operational and business approaches, and defense budget realignments. These sources might have to include additional acquisition programs or force structure, and to the extent they do, are likely to be much more problematic and controversial. However, if included, the opportunity costs and difficult choices that accompany the 1998 Summer Study recommendations could be better understood.

This year's task force has identified the following parallel technology and program paths to improve operational capabilities between now and fiscal years 2015 or 2020. Each path carries with it a different set of technical risks and funding requirements.

First, the summer study task force supports ongoing or new efforts which are of relatively low, modest, or moderate technical risk; have a payoff within about 10 years; and may have reasonably well-understood acquisition costs. These efforts include: (a) continuing to upgrade the current bomber fleet with improved precision and standoff weapons and better communications, maintainability, survivability, and mission planning; (b) converting four TRIDENT strategic missile submarines to be able to launch a variety of conventional weapons from vertical launch tubes; (c) enhancing the Department of Defense global grid and creating an integrated information infrastructure for command, control, communications, and intelligence dissemination; (d) fielding a family of advanced small, precision and standoff munitions and weapons; (e) modestly increasing funds for mine countermeasures; and (f) improving chemical warfare, biological warfare, and counter-terrorism defenses both overseas and in the United States. This latter initiative includes enhancing computer-based tracking and information capabilities, conducting overseas coalition exercises in protecting against weapons of mass destruction, and creating a second Chemical Biological Incident Response Force capable of homeland and overseas operations.

Second, the task force advocates new initiatives, which it believes carry higher technical risks and larger costs, and may yield results by about 2015. These initiatives include several major, new start acquisition endeavors which, in most cases, embody technical development risks and high acquisition costs but which may yield revolutionary military capabilities. These programs include: (a) a littoral warfare amphibious ship of about 60,000 tons, with a 600-foot deck, and which can function as an inter- and intra-theater airlift base and highly mobile offshore base; (b) a sea-based capable, intra-theater airlift aircraft with super short takeoff and landing (SSTOL) performance to succeed the C-130 tactical airlifter; (c) a fast shuttle intra-theater sealift platform; (d) a space operations vehicle capable of sub-orbital transit or launch of satellites or weapons; (e) a continuous global surveillance system located in space; and (f) a heavy-lift, high-altitude/long-endurance unmanned aerial vehicle for multi-mission operations.

In the near term, during the current and fiscal years 2000-2005 FYDPs, the task force believes that most of the resources to support the development of the recommended technologies and capabilities already are included in ongoing programs and existing and projected Department of Defense spending plans. An annual investment of approximately \$200 million – properly focused and directed – should be adequate to support most of the new or expanded activities. Most, if not all, of this amount should be available by maintaining ongoing efforts in these areas and through a modest reprioritization of funds and activities within the already-programmed resources of the individual armed Services and the Defense Advanced Research Projects Agency (DARPA).

Beyond the next FYDP, however, the task force recognizes that significant funds are required to move the more revolutionary technologies beyond initial development and carry them through demonstration and validation, engineering and manufacturing development, and deployment in weapons systems.

To some extent, funds for these activities should become available from currently planned and programmed efforts that no longer will be required due to the implementation of the task force's recommendations. However, these funds are unlikely to be sufficient by themselves to finance the recommended initiatives.

As a rough order of magnitude, development of any single new weapon system recommended might cost several billion dollars. Procurement costs for any new system might range from a low of $500 million to a high of several billion dollars. The task force reserves judgment whether, under severe defense budget constraints and absent modification of some ongoing efforts in other defense programs, projects, activities and force structure, these investment dollars will be affordable and available for development and eventual procurement of the recommended systems.

In several cases, the task force recommended acquiring capabilities to replace weapons systems which themselves represent significant improvements in military capabilities or which still have useful remaining service lives. It recognizes further that these factors might make it much more difficult to convince Executive Branch or Congressional decision makers to allocate the funds necessary to acquire the recommended capabilities on the projected timetables. The task force also acknowledged the increased burden associated with diverting scarce resources away from well-established programs with significant momentum or from already-reduced force structures being stoutly defended by their institutional adherents.

The task force is not prepared to say that, based on all these factors, any deviation from its recommended programs will seriously impair the nation's overall defense posture in the near- and mid-term. However, continued delay beyond a certain point will only serve to deny the men and women of our armed forces the capabilities needed to accomplish future missions. Underwriting Joint Vision 2010 and beyond will require a reprioritization of both R&D and procurement accounts.

The task force cannot say when that point will be reached. However, it recommends strongly that a prudent compromise be established between allocating funds to maintain or marginally improve the more traditional warfighting capabilities of the current acquisition programs and force structures and investing sufficient resources to acquire the more revolutionary capabilities embodied in the task force recommendations. Executive Branch and Congressional decision makers should consult closely in an effort to establish this compromise as they consider the recommendations contained in this study.

To fully understand the current and future funding requirements to implement its initiatives, the task force has several suggestions:

(1) Each of the Armed Services and the Defense Agencies – especially DARPA, the National Reconnaissance Office and the Defense Information Systems Agency – should identify those programs, projects, and activities already underway in its budget which fall into the technology and capabilities categories recommended here. OSD then should determine which of these endeavors should be modified or refocused to enable the Department to obtain the recommended capabilities within the recommended timetables. OSD also

should determine which new technology development efforts must be initiated for the same purposes.

(2) The Under Secretary of Defense for Acquisition & Technology should conduct a technical risk assessment – by technology and acquisition program – to determine the level of risks associated with acquiring the recommended capabilities on the recommended timetables.

(3) The OSD Director of Program Analysis and Evaluation – assisted by the OSD Comptroller and the USD(A&T), and in coordination with the Chairman of the Joint Chiefs of Staff – should cost out an annual and multi-year investment plan necessary to develop and deploy the recommended capabilities on the projected timetables.

(4) This effort needs to include an assessment of the advantages and disadvantages of specific tradeoffs between ongoing and already-planned science and technology efforts, acquisition programs, and force structures which could be modified – reduced, slowed, eliminated – to provide the resources necessary to obtain the capabilities recommended in this study by the projected dates.

(5) The detailed results of the implementation of the three preceding initiatives should be provided to the Defense Science Board no later than March 1, 1999, to assist the DSB in its future deliberations and efforts to monitor the implementation of the overall recommendations presented in this study.

(6) The Fiscal Year 2000 defense budget request and the FY 2000–2005 FYDP should be modified before submission to the Congress to include any technology development and other programmatic actions necessary to begin implementing overall recommendations of the task force.

In assessing the tradeoffs as called for in suggestion Number 4 above, no major weapons acquisition program or current active duty and reserve components force structure should be excluded from consideration.

Further, in order to moderate the financial burdens of acquiring the recommended technologies and capabilities, OSD needs to consider an incremental, "building block" acquisition approach wherever possible. This approach would concentrate first on developing fundamental "core" technologies that, if possible, would represent incremental modifications or upgrades to existing or about-to-be-fielded systems as well as the revolutionary foundation for new weapons systems. Secondly, this approach would concentrate on developing and deploying the more costly new systems, if future financial resources permit.

The task force believes that providing adequate resources to eliminate the current defense under funding problem and to acquire the new capabilities needed to protect the nation in the future is important.

ANNEX C:

Defense Science Board 1998 Summer Study Terms of Reference

THE UNDER SECRETARY OF DEFENSE
3010 DEFENSE PENTAGON
WASHINGTON, D.C. 20301-3010

ACQUISITION AND TECHNOLOGY

13 MAR 1998

MEMORANDUM FOR CHAIRMAN, DEFENSE SCIENCE BOARD

SUBJECT: Terms of Reference--Defense Science Board 1998 Summer Study Task Force on Joint Operations Superiority in the 21^{st} Century: Integrating Capabilities Underwriting Joint Vision 2010

You are requested to form a Defense Science Board (DSB) Task Force to address Integrating Capabilities Underwriting Joint Operations Superiority in the 21^{st} Century. The Task Force should focus on how new capabilities, operational concepts, and different force characteristics can be developed and integrated to underwrite Joint Vision 2010.

The Task Force should address the following tasks:

1. Review selected prior DSB studies for relevant capabilities and concepts that could be integrated into underwriting a 21^{st} Century Joint Vision 2010 force.

2. Examine warfighting benefits of potential advances in logistics.

3. Examine potential advances in technology that would enhance the warfighting and survivability of early entry forces to include, for example, global lift, battlefield mobility, information operations, and surveillance and reconnaissance.

4. Examine technological advances and technology fielding options in information technologies that would increase joint interoperability rapidly.

5. Assess the utility of emerging new technologies in areas such as surveillance, information systems, precision long-range weapons, platforms, and command, control and communications.

6. Examine future capabilities to better integrate and utilize space-in-warfare.

7. Examine the impact of the above tasks on DoD force characteristics.

8. Develop and evaluate one or two example operational concepts illustrating the potential force enhancements brought about by the new capabilities and force characteristics.

This study will be jointly sponsored by the Chairman, Joint Chiefs of Staff and the Under Secretary of Defense (Acquisition and Technology). Mr. Donald Latham and Gen. Larry Welch, USAF (Ret.), will serve as Co-Chairs of the Task Force. Mr. Jimmy MacStravic (OUSD(A&T)/S&TS/Office of Naval Warfare), Colonel James Lasswell, USMC (Marine Corps Warfighting Laboratory), and Colonel Ron Kurjanowicz, USAF (Battlelab Integration Division, US Air Force) will serve as co-Executive Secretaries. CDR David Norris, USN, will be the Defense Science Board Secretariat Representative.

The Task Force will operate in accordance with the provisions of P.L. 92-463, the "Federal Advisory Committee Act," and DoD Directive 5105.4, the "DoD Federal Advisory Committee Management Program." It is not anticipated that this Task Force will need to go into any "particular matters" within the meaning of Section 208 of Title 18, U.S. Code, nor will it cause any member to be placed in the position of acting as a procurement official.

J. S. Gansler

ANNEX D:

Task Force Membership

TASK FORCE MEMBERSHIP

CO-CHAIRMEN
Mr. Donald Latham*
Gen Larry Welch, USAF (Ret)*

SENIOR ADVISORS
Mr. Bert Fowler*
Dr. Robert Hermann*

EXECUTIVE SECRETARIES
Col Mike Fallon, USMC
Col Ron Kurjanowicz, USAF
Mr. Jimmy MacStravic, OSD

DEFENSE SCIENCE BOARD MILITARY ASSISTANT
CAPT Jim Lyons, USN

MEMBERS

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ANNEX E:

Assuring Availability of the Global Positioning System

ASSURING AVAILABILITY OF THE GLOBAL POSITIONING SYSTEM

INTRODUCTION

The Global Positioning System (GPS) is a vital, highly accurate geo-location, timing, and navigation system for a wide variety of commercial and military applications. GPS satellites transmit relatively low power signals from a medium earth orbit (MEO), 24-satellite, globe-circling constellation. Military missions require operation within range of GPS electronic jamming equipment or in geographic areas which deny access to the GPS constellation signals such as heavy forested areas and rugged terrain – masking electronic access to the GPS space segment. The user's operating environment thus places constraints on the ability of GPS receivers to receive the necessary timing and positioning data required for lock-on and accuracy. Advanced L-band (L-1 @ 1575 MHz, L-2 @ 1227 MHz) GPS receivers employing adaptive nulling antennas and highly integrated, closely coupled inertial measurement units (IMU) are just beginning to address the issue attendant to deliberate or self-induced jamming. This Annex summarizes current GPS capabilities, discusses potential enhancements, and outlines operational approaches to alleviate the considerable risk to operational and mission effectiveness associated with loss of GPS signaling information.

CURRENT GPS CAPABILITIES

GPS is a space-based navigation, timing reference, and geo-location system using a constellation of 24 satellites in 12-hour, 20,000 km orbits. The orbits are precisely known and at any instant each satellite position is known to within 3 meter accuracy. Each satellite transmits low-power (20 watt), L-band, spread-spectrum (CDMA) signals. Specially designed user equipment can receive these signals even though GPS transmitted power density is 160 dbw, equating to at least 30 db below a receiver's threshold noise floor. GPS receivers lock-up signals which are this far below the noise threshold and track code as well as carrier phase. Each GPS satellite transmits signals at two frequencies in L-band. These signals are transmitted simultaneously to permit corrections, induced by ionospheric signal-distortions (timing and position errors), to be applied by error-correcting, computational algorithms embedded in "user" receiver processors.

Two types of signals are transmitted at L-1: an encrypted 10 Mbit/s (P(Y)) signal for military use, and a 1 Mbit/s clear/acquisition (C/A) signal for unrestricted tracking and for use by encryption-equipped users in acquiring the "military" signal. At L-2, P(Y) is the only signal transmitted. With these signals, the military user can track ten times more accurately than can the standard commercial user who is limited to the C/A signal only. Further, the military user can track signals at both frequencies and obtain ionospheric corrections to enhance accuracy and precision of the received signal.

Tracking at least four GPS satellites permits user equipment to estimate the corresponding four pseudoranges (each containing a common bias due to clock error) from which position and

clock error can be computed by multilateration methods. With this approach, a user receiver could, under ideal conditions, estimate its position to about 10 meters CEP using C/A code on L-1 alone. But as this capability became widely accessible, even to a potential adversary, an intentional distortion (selective availability (SA)) was added to the C/A signal on L-1 increasing the achievable CEP to 30 meters. At present, SA is included on the L-1 signals, although the United States has announced its intention to remove SA in less than 10 years.

As indicated above, GPS signals on the earth's surface are very low level, ~ 10^{-16} watts. GPS low-level signals are tracked through use of spread spectrum CDMA coding and a coherent integration process that collects all energy from the signal over the entire coherent integration interval. Processing gain can be obtained when the signal structure, including carrier phase, is precisely known. As a result, military users with decryption equipment benefit from processing gain resulting from use of the more precise, but encoded, P(Y) signal.

Such low-level GPS signals are thus susceptible to jamming or other perturbations. When "user" equipment is in proximity to electronic jamming signals, the GPS receiver has difficulty acquiring and tracking GPS signals. Of course the range at which this occurs depends on the power transmitted by the jammer and on the "user's" equipment function. This range also depends on the user equipment design details that can vary significantly. Some receivers designed for use on maneuvering aircraft must compensate for platform motion by coupling the GPS receiver's data stream to the aircraft's IMU. With such a receiver/IMU combination, effective jamming range depends more on the quality of the IMU. Some user equipment is intended to operate close to jammers; in such cases, anti-jam antenna systems are included within the user equipment suite to assure improved GPS operation.

Table E-1 shows "jammers-to-signal" (J/S) thresholds at which various user equipment functions may be lost due to jamming. Figure E-1 shows J/S power ratios as a function of range to the jammer and jamming power being employed. When combined with the data in Table E-1, for example, a one-watt jamming signal (properly oriented) can deny C/A code acquisition out to 100 km. Such jamming effects have motivated strong interest in GPS user equipment anti-jam enhancements.

Table E-1. Jammer-to-Signal Levels for Representative GPS Receiver Functions

Function	J/S (db)
C/A code acquisition	27
P(Y) code acquisition	35
C/A code lost lock - conventional receiver	47
P(Y) code lost lock - conventional receiver	54
P(Y) code lost lock - advanced receiver	65
Conventional receiver with nulling antenna	79
Advanced receiver with nulling antenna	95

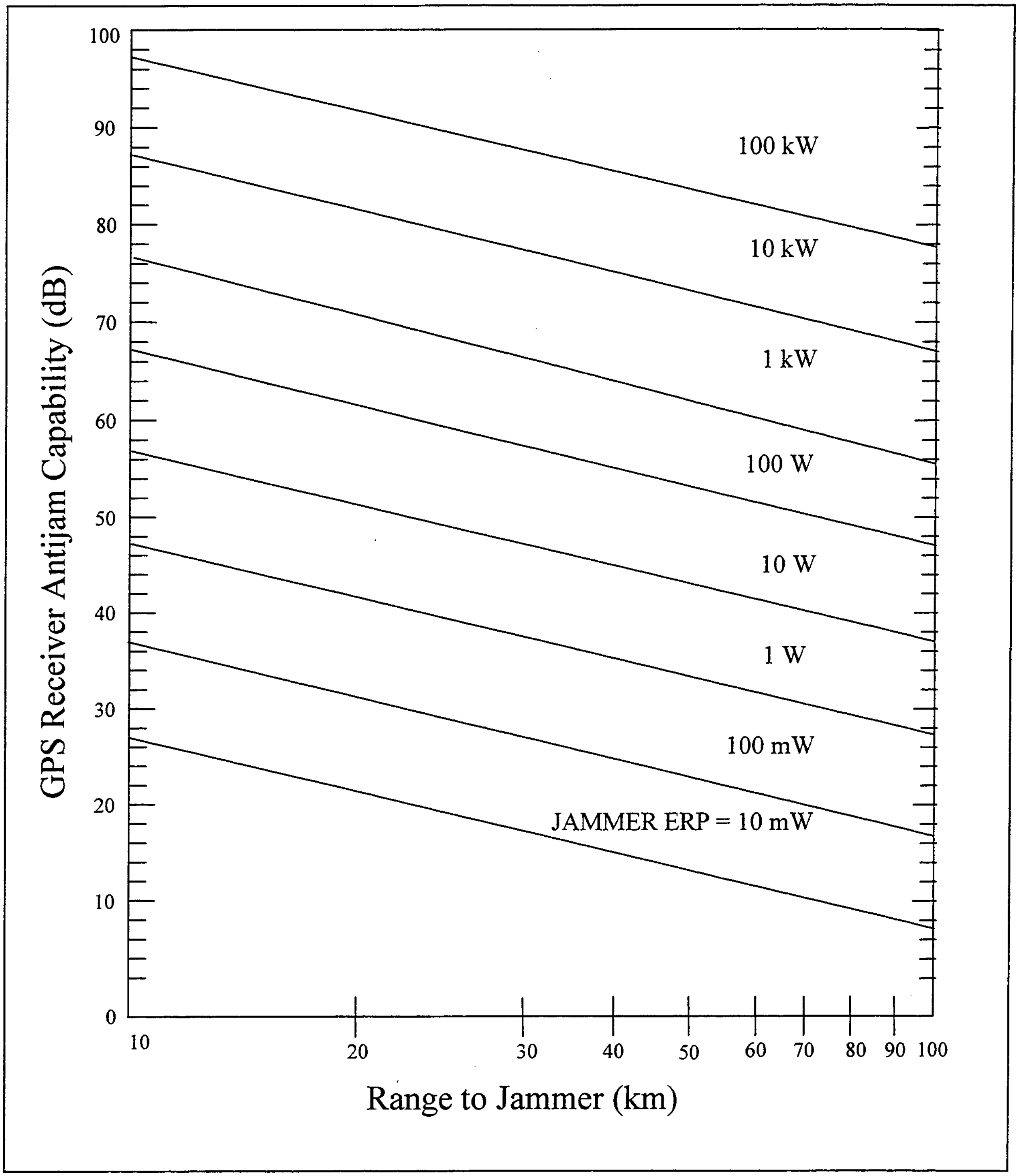

Figure E-1. GPS Jamming Calculations

ADVANCED GPS RECEIVER PROJECTION OPTIONS

Many improvements to the presently available military, encryption-equipped GPS receivers and weapon system receivers have been suggested; some have been demonstrated.[1] Key user equipment shortcomings addressed have been:

- ***Increased Integration Time***. As indicated earlier, the user receiver must coherently integrate the GPS signals to obtain processing gain. Doing so requires knowledge of the signal phase. As the integrating receiver is tied more closely with an aircraft IMU, and as that IMU's quality improves, the phase is more accurately included in the integration process; integration time and coherent integration gain increases, and jamming resistance is enhanced. A more advanced GPS receiver is expected to be 10 or more dB better than a conventional receiver as a result of this closer receiver-IMU coupling.
- ***Multiple Correlators***. As indicated in Table E-1, signal acquisition is one of the weaker receiver functions. Furthermore, under many operational circumstances, most military receivers must acquire the C/A signal first. This problem suggests the development of receivers which can directly acquire the P(Y) signal.
- ***High Accuracy, Miniature Clocks***. Direct P(Y) acquisition can be accomplished quickly if there is little initial time uncertainty. Cesium standard clocks, packaged in a few cubic inches, are being developed for tactical use and should also become common components of GPS receivers in a few years.

The enhancements associated with increased integration time will also contribute to more jam resistant acquisition as the ability to search for correct P(Y) code phase improves. Longer integration time and less initial doppler uncertainty will increase the acquisition threshold above the 35 dB level listed in Table E-1. Still there are limits to integration gain. New methods may provide a few more dB of acquisition immunity once high accuracy IMUs and precision clocks are included in a receiver design.

ANTENNA-BASED ENHANCEMENTS

All GPS receiver functions will benefit from antennas that provide some gain in the direction of a satellite and simultaneously place nulls on jammers. Several approaches to this form of increased jamming resistance are being developed; some early versions are already in use.

Adaptive Nulling Antenna. These antenna can place deep nulls in the direction of several strong jamming sources. As a result, jamming power reaching the receiver is attenuated sharply. The adaptive nulling antenna relies on differences in the direction of arrival between the desired GPS signal and the undesired interference. With these methods, interference can be rejected by 20 to 40 dB or more, as long as there is sufficient angular displacement between the GPS signal direction and that of the interferer. Fortunately, such conditions are typical of the geometries relevant to most GPS jamming scenarios.

[1] The *Report of the Defense Science Board Task Force on Global Positioning System, Phase II*, February 1997, discusses improvements to GPS receivers in more detail.

The Controlled Radiation Pattern Antenna with its antenna electronics unit uses a seven-element array, shown in Figure E-2 and adaptive nulling processing to provide anti-jam protection in a hostile environment, while maintaining good GPS performance in a benign environment. This nulling system is used on the F-15, F-16, and other Air Force platforms today. Based on extensive testing, the antenna can contribute, on average, 10-25 dB to the jamming resistance of airborne GPS user equipment when a small number of jammers generate the interference.

Performance enhancements to this system are being investigated. These focus on: 1) providing gain in the direction of a specific GPS satellite; 2) more effective nulling patterns in the presence of multiple interference sources; and 3) enhanced gain in the direction of low-elevation satellites even when nearby jammers are nulled. These enhancements should provide a more robust 20-30 dB jamming rejection when multiple (>3) jammers are present and 30-40 dB nulling when a few (≤ 3) jammers are present.

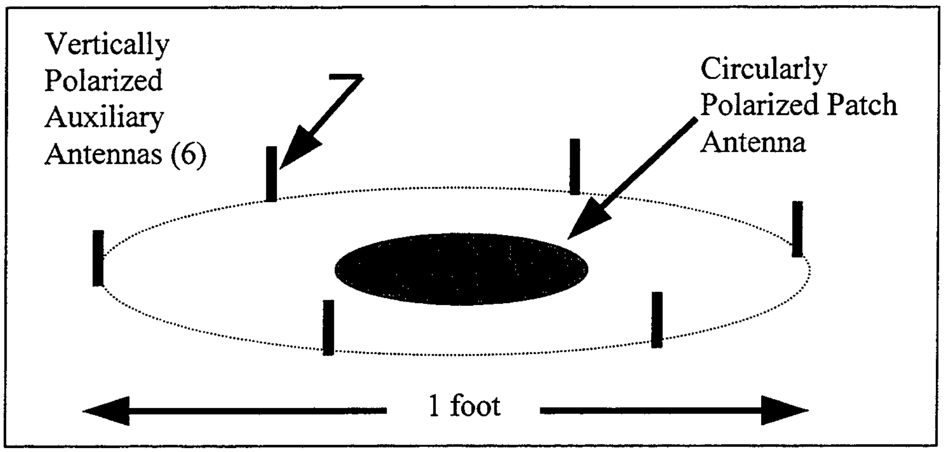

Figure E-2. Controlled Radiation

Polarization Nullers. A potential low-cost and promising solution to the anti-jammer problem is polarization nullers. These have been demonstrated to provide 20-30 db jam resistance at a cost low enough to use on low-cost munitions, weapons, and navigation systems.

Low-elevation Antenna Patterns. Antennas can be designed to operate in two modes: in the normal mode, with no anti-jamming capability, the antenna pattern is designed to optimize horizon-to-horizon coverage for maximum satellite acquisition capability when no jammers are present; in the anti-jamming mode, the low-elevation coverage is sacrificed to attenuate the ground-based jamming signals relative to the (generally) overhead satellite signals. It is expected that these two modes will be switch selectable. Figure E-3 conceptually illustrates this approach to antenna design. A jammer at the horizon or below will be attenuated at least 20 dB compared to a satellite above 20° elevation.

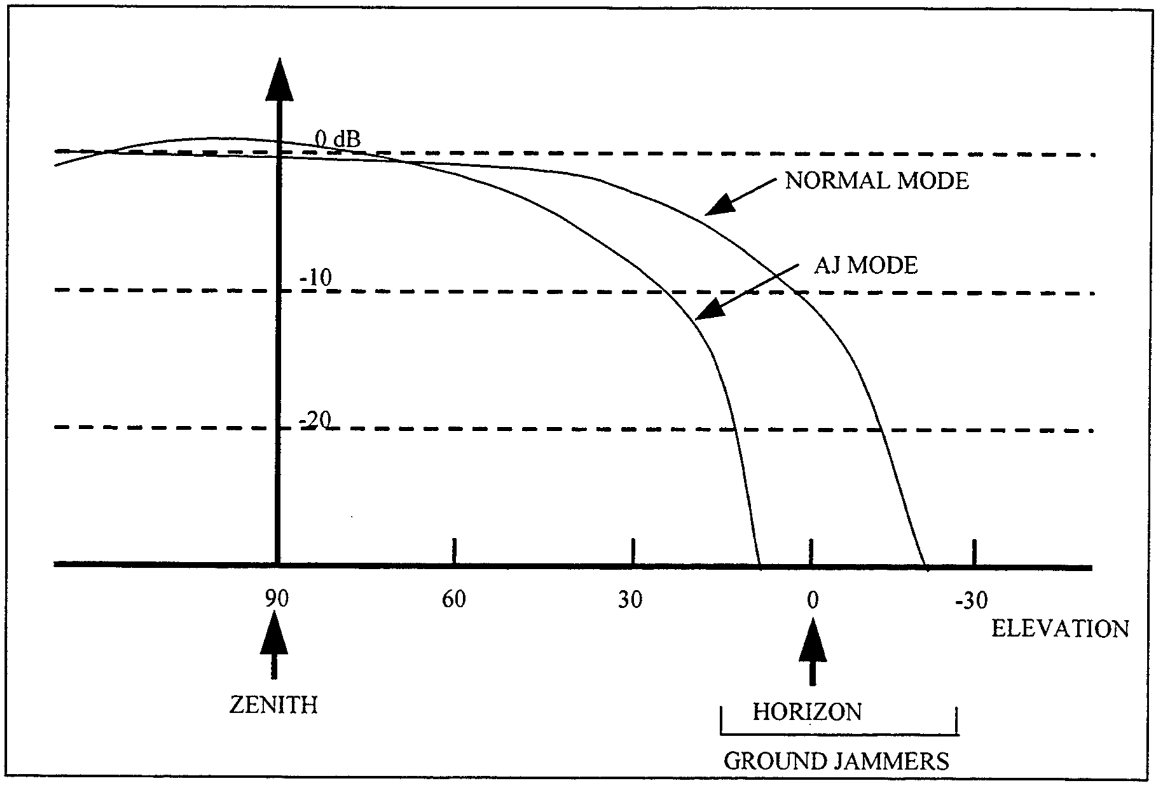

Figure E-3. GPS Dual Mode Antenna Patterns

Airframe Body Shielding. Typical aircraft GPS installations place the antenna on the upper surface of the airframe where there is usually a clear line-of-sight to the GPS satellite constellation. When the aircraft is in level flight, any ground-based jammers will be at the horizon or below, implying that the airframe will often lie between the aircraft GPS antenna and the ground-based jammer; this geometry should significantly shield GPS from the jamming interference.

Surprisingly, this shielding has not been accurately quantified with careful measurements of GPS antennas installed on full-size airframes. Most antenna measurements appear to have been made with full-size antennas mounted on relatively small sections of a simulated fuselage. These measurements were planned to provide accurate estimates of the GPS antenna gain and mainlobe shape, but not the shielding provided by the entire airframe. Unfortunately, it is difficult to model the airframe and antenna accurately at GPS operating frequencies; thus reliable computer model estimates of airframe shielding are not available.

Like any electronic countermeasure or electronic counter countermeasure problem, diversity of solutions is a critical aspect of future implementations.

Enhanced Accuracy – Differential GPS

There are many potential applications of GPS which require accuracies much better than the 100 meters (95%) afforded by the C/A code with SA active, or even the 20 meters with SA inactive. Examples are ship navigation in narrow channels, aircraft landing guidance in instrument meteorological conditions, or precise position determination for offshore drilling. The requisite accuracy for such applications can be achieved by so-called Differential GPS

(DGPS). The basic approach is to measure the errors in the signals received from each GPS satellite in view at a precisely known location, and then to broadcast these errors to the user receiver. The user receiver then applies these errors to its measurements from the satellites, achieving a positioning accuracy of 10 meters to centimeters, depending on the specific technique and equipment used. Most DGPS systems also provide a message indicating whenever a satellite is transmitting erroneous data and should not be used; this is called an "integrity message."

Both the US Coast Guard and the Federal Aviation Administration (FAA) are implementing DGPS systems to serve the navigation and guidance needs of their respective communities. The Coast Guard is implementing a local area DGPS system to cover the coastal areas and principal inland waterways of the United States. Full operation of 61 sites has just begun. The FAA is developing the Wide Area Augmentation Systems to meet the navigation and landing guidance needs of the national airspace system for Category I instrument approach minimums. Local Area Augmentation Systems are also being planned for Category II and III operations.

Numerous privately operated DGPS systems have been developed; some are operating today and many more are expected to operate in the future. These systems utilize the C/A code. It is also theoretically possible to operate a differential system that uses rebroadcast Y-code without the benefit of a cryptographic key. Such a system has the potential to provide enhanced accuracy as well as enhanced jamming resistance.

As indicated above, the United States has committed itself to eliminating selective availability within ten years. This means that C/A users will have the 20 meter accuracy associated with this code, shown in Figure E-1. The wide availability of this accuracy, or even better, in areas where DGPS has been deployed will improve enemy navigation capabilities; these potential improvements should be considered in small unit operation planning.

GPS Use in Small Unit Operations

In some small unit operations, it may be necessary to cold start a GPS receiver without access to another operating unit. As long as C/A signals are unjammed, this is not an issue. If GPS jammers are present, another signal acquisition strategy will be required. Direct P(Y) acquisition has already been discussed above.

Hand-held GPS units capable of operating with P(Y) code will no doubt be important players in these operations. Such units have certain problems:

- Large array antenna-based, anti-jamming enhancements will be difficult to implement. A polarization nulling system for portable lightweight GPS receivers (PLGR) should be considered.
- Small units will be required to operate in urban areas where reflected signals from buildings generate multipath signals, which are sources of signal tracking error.
- Buildings will limit the areas where there are direct views of at least four GPS satellites.
- PLGRs will be required to operate under tree canopies and other foliage which attenuate the GPS signals.

On the positive side, the urban and foliated area will make GPS jamming of PLGRs more difficult.

CONCLUSIONS & RECOMMENDATIONS

As this paper illustrates, there are significant and growing challenges ahead as military systems increasingly place accuracy and timing requirements on reliable and sustainable access to the GPS space segment. A well-funded, focused R&D program should pursue a wide menu of high-payoff anti-jamming technologies. Given that the GPS Block II full constellation is at least 15 years in the future, an active R&D effort begun now and implemented over the next several years (5-10) could provide DoD with the necessary capability to modify requirements for the future space segment and the components comprising the ground segment. With ever increasing military dependencies associated with access to GPS data, user equipment anti-jamming capabilities providing a reasonable measure of assured access is critical.

The recommended areas for increased R&D attention, in priority, order are:

- Spatial rejection, to include:
  - Theory and computer modeling;
  - Experimentation (anechoic chamber measurements, flight tests);
  - Develop beam forming, polarimeter, and nulling arrays;
  - Develop appliques addressing horizon nulling and multi-point "nullers";
  - Investigate pseudolite solutions and wide-area differential GPS concepts (employing P(Y) code, ground-based registration systems);
  - Investigate very low cost "canceller" schemes;
  - Investigate and experiment to further the concept of using a third means of timing synchronization via an L-1 orthogonal code (the notional "LM" code) and other similar spread spectrum coding techniques such as employing "Manchester" coding; and
  - Provide impetus in the R&D effort for "dual-use" in commercial and civil sector applications such as cellular systems and power grids.
- Investigate further the concept of "Lock-on Before Launch" (notionally the idea of locking up all JDAMs in a B-2 bomb bay)
- Continue development of low-cost, accurate IMUs. Expanded R&D into further understanding more closely coupled IMU technologies (consider microelectromechanical (MEM) technologies vice continuing with ring laser and fiber optic IMU solutions).

ANNEX F:

Joint Rapidly Deployable Early Entry Force

JOINT RAPIDLY DEPLOYABLE EARLY ENTRY FORCE

Rapidly deployable early entry forces provide the United States with an option to place a forward air, naval, and ground presence in politically important conditions without the high risks faced by the 82nd Airborne Division when it deployed in the first days of the 1990 Gulf War. A few thousand soldiers deployed early, and trained and equipped for the specific high payoff tasks which occur early in a campaign, can replace the need for a much larger number of troops later if they are part of a joint air, naval and ground integrated strike force. These compactly packaged teams can double or triple the fighting value of an allied brigade for the price of a C-141 sortie.

This Annex describes in more detail the force characteristics of the land forces component of the Joint Rapidly Deployable Early Entry Force, introduced in Chapter 3. These land forces can be an early entry Marine Corps force and/or an early entry Army force or a combined Marine/Army force as the operational environment demands. The rapidly deployable early entry land forces are composed of three elements: 1) Rapid Response Liaison and Combat Support (RRLCS) force; 2) Light Infantry Response (LIR) force; and 3) Light Mechanized Strike (LMS) force.

At the outset of a conflict, it is important to leverage the potential of land power already on the ground in a crisis. The RRLCS force – a rapidly deployable joint force with a small footprint – coordinates the US response with allied efforts, once inserted into the theater. It integrates "first hour combat power" of air, naval, and long-range ground fires; provides intelligence; and enhances command, control, and communications.

Next, it is important to protect key "entities" and prevent the loss of ports, airfields, or political centers to enemy armored or airborne forces. For this mission, the LIR force is envisioned as a highly mobile force of 6,000 to 10,000 personnel. Composed of small, mobile, and light air deliverable (using V-22, helicopters, and the SSTOL) fighting units, this force is equipped with anti-armor weapon systems and is able to defeat elements of heavy armored forces through independent and coordinated actions using remote fires. These ground fighting elements are an integral part of cooperative engagements using advanced information systems, sensor systems, and standoff organic precision munitions, supported by fires from long-range air, ground, and sea systems.

The LIR force is fully airborne, air assault, or air/land mobile. It contains no vehicles or organic equipment weighing more than tactical rotor craft are capable of moving and intra-theater lift is capable of deploying directly to tactical locations. The family of vehicles designed for this force requires less than half the airlift of those used today. Once on the ground, this force is capable of securing critical facilities or terrain – such as key political centers, ports, or airfields – and blocking limited armored advances. The combination of information age communications, fire control, and planning systems; multiple layers of internetted sensors; and stand-off precision weapons allows the light infantry force to be very potent in defensive situations. It is envisioned that this force can be deployed and in combat operations anywhere in the world within 24 hours.

The Light Mechanized Strike force of 6,000-10,000 soldiers – comprised of five or six agile tactical units of approximately 500 persons – is a light, mechanized, electronically internetted

mobile force capable of potent anti-armor missions to complement early available standoff fires from land, sea, or air. It is fully air assault mobile by C-130 or C-130 follow-on aircraft, such as the SSTOL, and capable of strategic deployment by air. Its fast, agile, protected vehicles permit limited offensive action. The force has three tiers of lethal anti-armor capabilities: long-range precision fires delivered by rockets, missiles, naval gunfire or tactical air; organic precision indirect and beyond-line-of-sight fires; and rapidly responsive hypervelocity line-of-sight anti-tank (LOSAT) missiles and medium caliber guns. If required, this force might be inserted in the enemy rear and supported there by air. LMS systems are designed for long endurance and economical expenditure of on-board consumables. The LMS force can be deployed and in operation effectively within 24-48 hours, independent of ports and airfields. To train and field such a force is a significant cultural, technical, and operational challenge.

FORCE CHARACTERISTICS IMPLICATIONS[1]

The LIR force deploys in half the lift of a current airborne Division Ready Brigade, is more flexibly inserted, and is several times more capable of securing key terrain for later exploitation. The LMS force provides a new land power capability very early in a crisis, when light mechanized armor can seize the initiative from a potential aggressor.

In most aggression crises, a hostile agressor will attempt to quickly overpower the ground forces of his neighbor. It will be important to strengthen the capabilities of allied coalition neighbor forces and to optimize the use of "first hours combat power." The aggressor will want to break up the neighbor's forces and intermingle his forces with theirs, thus complicating targeting and raising risks of fratricide. The attacking enemy will also want to rapidly secure urban centers for political and operational reasons. If the aggressor accomplishes these actions, precision weapons are less effective and the United States loses some of its asymmetric advantage. The RRLCS teams can help mitigate against this set of events.

LIR forces take advantage of one well-known phenomenon of information age warfare: firepower potential has grown at a geometric rate while mobility advances tend to be arithmetic. This means that, at least in ground combat, defensive combat power grows at a faster pace than offensive combat power. Light forces, equipped with modern weapons, will tend to defend more successfully even against near peer attackers. Therefore, there is a great benefit to deploying light forces early in a crisis, when the first order of business tends to be either deterrence or defense. Thus these early defensive tasks can be accomplished at a reduced cost in lift. When the equipment for such a force harnesses modern technology to improve compactness in transit without sacrificing functional utility in combat, the pay off can be very dramatic.

The LMS force turns a reactive ground battle against enemy armor into a proactive seizure of the initiative. Taking advantage of the tactical stability provided by the RRLCS, an enhanced indigenous coalition force and the LIR force, the LMS force can engage in asymmetric maneuver to exploit the effects of superior US surveillance, targeting, and long-range firepower at this early stage of the campaign. This force might be inserted deep in the enemy rear against supporting infrastructure, provided there is sufficient joint suppression and support. This LMS force can also fight armored formations directly and can defend against large numbers. Key to

1 Volume II contains analytic analysis and modeling results, developed by RAND, for a notional 21st century force engaged in a combined arms conflict.

such effectiveness is superb situational understanding with assured knowledge superiority and effective employment of joint precision indirect supporting fires. Chapter 4 describes how to achieve that capability.

The LMS force takes advantage of the defensive differential of advanced information age weapons and mobile protected equipment. This force is much more capable than the LIR force in defensive situations in open terrain. The protection provided by the light armor, the superiority of situational understanding, and the ground mobility of its systems allows this force to defend in depth with large frontages. Its operations are dependent on and coordinated with long-range, joint precision fires. At this point, the LMS force can seize the initiative and set the stage for decisive action by even more potent follow-on ground forces, if required.

The combined capabilities of the RRLCS, LIR, and LMS forces could be decisive.

ADVANCED VEHICLES

Two new families of combat vehicles need to be developed to support the Joint RDEEF. The RRLCS and LIR forces need a family of vehicles with high payload-to-weight ratio, advanced space frame architectures, enhanced energy efficiency, high reliability, and compactness for strategic transit. Enhanced energy efficiency and high reliability are important in early entry operations for two reasons. First, the value of each system inserted into early entry situations is high and losses are difficult to replace. Second, a low consumption rate of parts, fuel, and other supplies means that the arrival of fighting power is proportionally accelerated and the inserted force can accomplish more before requiring replenishment. The vehicles and their payloads must use space in strategic lift very efficiently, unlike the vehicles in units of this type today, which were designed neither as a "family of vehicles" with complementary capabilities nor with compactness in mind. Also the loads of current vehicles tend to exceed space requirements before they meet weight limits. Some vehicles and loads should be stackable and configured to fit the size and dimensions of standard load pallets and commercial shipping containers.

The LMS force needs a family of carrying and fighting vehicles with a high protection-to-weight ratio, enhanced energy efficiency, high reliability, rapid ground mobility, superior trafficability, and compactness in strategic transit. The purpose of this family of vehicles is to provide a very high degree of mobile protected ground fighting power tailored to exploit the special conditions encountered early in a counter-aggression campaign or those encountered later in the fluid, non-linear engagements in the enemy's rear areas.

The combat-loaded command and control, fighting, troop carrying, weapons, and combat support vehicles of this fleet must be transportable – singly or in pairs – by the current C-130 fleet and the proposed SSTOL follow on, described in Chapter 4. All assets in the unit should be transported within these limits. This configuration greatly expands air insertion opportunities and thus the flexibility of this force. Fuel efficiencies and equipment reliability are as important to this force as to the LIR force. Rapid ground mobility and high trafficability are important because protection is derived in large measure from speed, flexibility, and unpredictability of movements. To the extent possible, cargoes use standardized dimensions for civil cargo aircraft for movements to intermediate staging bases when required. Cargoes are also designed for rapid transloading from strategic transports to intra-theater aircraft for tactical insertion.

Both the LIR and LMS forces would be supported by a light, advanced aerial attack/reconnaissance platform (AAA/RP) that would perform two functions. First, it would provide enhanced scout/reconnaissance capabilities using organic sensors. By 2010 these sensors could include fifth generation Forward-Looking Infrared (FLIR), follow on to Longbow radar, and signals intelligence intercept geolocation targeting capabilities – similar to that deployed in Guardrail today. Second, the AAA/RP would be capable of engaging targets at a distance with organic firepower such as fire-and-forget advanced Hellfires. In all cases, the AAA/RP would be electronically internetted, using the Integrated Information Infrastructure, to other friendly units on the battlefield and would obtain access to additional intelligence, surveillance, and reconnaissance information from off-board sources through two-way advanced digitized communication systems.

By 2015, the US military will have extensive operational experience with tilt rotor aircraft as the V-22 enters the force and gains operational flight hours. The tilt rotor has several advantages over the helicopter in AAA/RP missions. Its longer range and speed performance may lead to enhanced self deployability and cross-battlefield mobility. Its variable rotor plane orientation capability enables interesting tactical maneuvers in close combat situations, such as backing up in down-slope terrain while still tracking or engaging enemy units. It has disadvantages as well. The tilt rotor configuration is likely to have larger radar and infrared signatures, particularly in the aircraft mode and uncertain ballistic damage performance against small arms fires. An overall system performance analysis needs to be made prior to determining which aircraft configuration makes most sense for the AAA/RP mission. In either case, the aircraft avionics suite should include the advanced target acquisition and munitions described above and advanced aircraft survivability equipment – including advanced radar warning receivers and jammers, missile launch detection and tracking sensors, and an active infrared missile seeker defeat system.

ANNEX G:

Mixes of Fires and Maneuver for Halting Invasions in Mixed Terrain

MIXES OF FIRES AND MANEUVER FOR HALTING INVASIONS IN MIXED TERRAIN

BACKGROUND

This Annex summarizes supporting analysis accomplished by RAND for the DSB summer study.[1] The analysis involved a mix of low- and high-resolution simulation, including gaming. The intention was both to provide insights to the study and to indicate the power of using a mix of analytical approaches in examining future-warfare issues.

Analysis for the 1996 Study. This work built on analysis conducted for the 1996 DSB Summer Study, which assumed more open terrain. The analysis established a strong case for assuring that any "brigade-sized unit" that might be inserted early to stem an invasion should *not* be left to depend entirely on long-range fires for its survival and effectiveness. Even with substantial volume of long-range fires, there would be a significant likelihood of enemy "leakage," which would mean the demise of the small units without organic capability.[2] However, organic capability such as short-range precision fires of the Enhanced Fiber Optic Guided Missile (EFOGM) variety provided a significant hedge. The analysis also demonstrated the value of having large-footprint weapons, mid-flight updates, or loitering weapons. Any of these could compensate for location-prediction errors caused by long flight times and, to some extent, for enemy dispersal. The report of the DSB's analysis team summarized this work and also included discussion of the situational dependence of long-range fire effectiveness. It also provided a more speculative discussion of potential countermeasures to long-range fires. This background helped shape the analysis for the 1998 study.

Analysis Focus for the 1998 Study. Against this background and because of the study's general emphasis, the specific features of the operational environment chosen for 1998 included:

- An objective of halting an invasion with light early-entry forces, without the luxury of great depth.
- Mixed terrain rather than open desert.
- An intelligent adversary who would use relatively straightforward tactical countermeasures to US precision fires.
- The presence of a defended coalition ally with small but moderately competent ground forces.
- Use of long-range precision fires involving strategic and long-legged tactical air forces, plus Army and Navy long-range missiles.

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1 The analysis is further documented in Volume II. The high-resolution work described here was led by John Matsumura and Randall Steeb.

2 Although this result may seem unremarkable in retrospect, it is of interest that at the time of the 1996 DSB study enthusiasm for long-range fires was so high that many were asking why it was useful or necessary to have any people at all on the ground. Further, early operational concepts often assumed that the ground forces would have only personal weapons. The argument was that the small teams would merely be acting as sensors, should avoid engagements at all costs, would not need organic fires, and therefore should be kept as light and deployable as possible. The simulation-based analysis helped alter intuition on such matters.

- Interest by the Joint Task Force commander in the option of employing small Army and Marine ground-force maneuver units to attack early into the enemy's rear area.

All of this proved highly consistent with the concepts for rapidly deployable light infantry forces for early entry.[3]

The analysis for the 1998 summer study built on ongoing RAND work. The broader, exploratory analysis drew on a study for OSD and the Joint Staff.[4] The high-resolution analysis started with a detailed database and scenario developed for the Army After Next project. It was necessary to modify the forces and strategies substantially to increase jointness, reflect the time period of interest (roughly 2010-2015), and represent particular issues raised by the DSB.

Results of Broad Exploratory Analysis

Low-resolution work focused on "exploratory analysis" to provide a high-level view of the factors that matter in accomplishing a halt in a shallow theater. Since issues of warning and mobility were being addressed elsewhere, the analysis focused on the favorable case in which appropriate forces could be available on D-Day. Key observations were as follows:

- US success might depend heavily on high competence in its C^3I and reconnaissance, surveillance, and target acquisition (RSTA) operations from the outset of war. Although it is utterly ahistorical to do so, most studies assume this without comment. Testing this assumption – and developing methods for training the relevant staffs quickly during crisis and deployment – should be a priority task for joint experimentation.
- Although most studies and war games have assumed that the effects of fires are proportional to the number of sorties or shots, it would not be surprising if there were sharply diminishing returns. This should be tested with both high-resolution simulation and joint experiments confronting human operators with large numbers of targets, large numbers of platforms and weapons, short decision times, and with imperfect RSTA, fusion, and decision aids.
- Early long-range fires would demand the D-Day availability of good RSTA. Even if some weapons that are not particularly vulnerable to air defenses could be employed from D-Day onward – such as stealthy aircraft, MLRS/ATACMS, arsenal-ship or arsenal-bomber TACMS – their effectiveness would strongly depend on RSTA. Since platforms like J-STARS could be highly vulnerable, there is a need for early deployment of survivable RSTA assets such as high-endurance, low-observable UAVs, satellites, or both.[5] This is because – despite many studies assuming rapid suppression of enemy air defense (SEAD) – it is questionable whether that could be achieved in practice against a clever adversary who might, for example, maintain

3 Chapter 3 and Annex F discuss the rapidly deployable early entry forces.

4 Paul K. Davis, David Gompert, Richard Hillestad, and Stuart Johnson, *Transforming the Force: Suggestions for DoD Strategy*, RAND Issue Paper, 1998.

5 It remains unclear how survivable aerial RSTA platforms can be early because of their need to radiate. The answer depends on details such as SAM range and RSTA-platform altitude, standoff, and signature. The best solution to the overall problem is likely a mix of several sources of RSTA, including friendly ground units and satellites.

some surface-to-air missiles (SAMs) in hiding until several days into the campaign. Mobile SAMs and integrated air defenses would pose additional serious difficulties.

- For related reasons, it would be valuable to have more delivery platforms that could employ weapons *before* completion of SEAD. These might be, for example, stealthy future bombers or UCAVs, or ground or naval-based missiles such as those that might be launched from converted Trident submarines.
- Because of the importance of the adversary's speed, especially in shallow theaters, it would be imperative to leverage the defender's forces to the maximum extent possible. Even if the only effect were to slow the daily advance rate substantially (for example, from 80 to 30 km per day), that might be quite important. This is one reason for emphasizing the leveraging of allied coalition forces capability.
- The effectiveness of air-delivered long-range fires might be drastically reduced by plausible tactical countermeasures such as *dash tactics* in which ground forces would be on the road only 2-3 hours per day, at random times, as shown in Figure G-1.[6] Implicit in most low-resolution work is the assumption of long uniform columns and movement matched in time to the uniform arrival of sorties scheduled well in advance. If the attacker used dash tactics, most of the sorties would have no targets – unless they could detect and attack forces under camouflage or in terrain-masked hides. The counter countermeasures for air forces here would include long-loiter missions (essentially "CAP missions"), strip alert, super-long-loiter systems such as might be possible with modified bombers or other platforms such as HAE UAV's, FOPEN radar sensors with GMTI, and a mix of weapons for striking moving area targets and stationary area and point targets.[7]

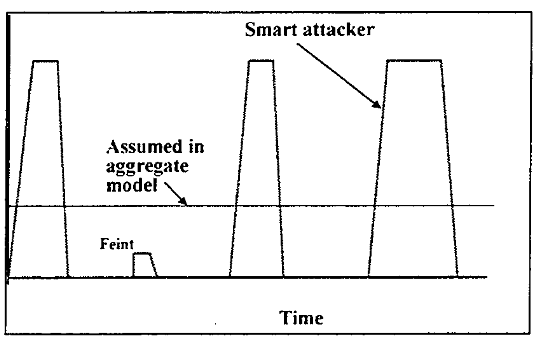

Figure G-1. Dash Tactics (Enemy vehicles on road versus time)

6 Tactical forces can move at 30-60 km per hour, whereas higher level studies usually assume – based on historical experience and doctrine – that sustained movements are on the order of 60-100 km per day. The apparent discrepancy here is that units actually move only a small fraction of the time because of logistical and command-control factors. Although it is normal for a given unit to move only a small fraction of the day, it would be more challenging for the attacking commander to accomplish an entire army's move in such a "dash" fashion. Further, success would depend on the availability of hides.

7 As discussed in the analytic portion of the material in Volume II, RAND examined some of these issues with narrowly focused, special-purpose entity-level models that were simple enough to work with readily, but which had enough detail to illuminate the "game" of measure-countermeasure that the attacker and defender would have to consider. Only a start on such work was possible for the summer study, but it was clear that it has potential value.

SURPRISING RESULTS STIMULATED BY HIGH-RESOLUTION ANALYSIS

Most of the high-resolution work used a Janus game board with entity-level representation of armored and other enemy vehicles and a number of specialized models representing weapon-system sensors and sensor logic during attack of targets. It represented RSTA and command-control issues parametrically in terms of detection and identification probabilities and delay times.

The results of simulation were quite surprising, even to experienced analysts and military officers. In retrospect, this was due to some common misconceptions: (1) that roads are open areas or, if not because of canopy, that successive open areas will be good detection and killing zones; (2) that detecting any part of a column is enough to project when some part of a column will be at subsequent open areas; (3) that arriving weapons detecting targets in open areas will kill them; (4) that "brilliant weapons" are at least smart; (5) that large-footprint weapons (such as BAT) can compensate for moderate errors in predicting target locations; (6) that high levels of fire, even if wasteful, would at least assure kills; and (7) that counter countermeasures will come along about as fast as countermeasures.

To put it differently, expectations before the analysis were that effectiveness would be somewhat, but not drastically, lower than obtained for past scenarios with moderately dispersed enemy forces in desert terrain.

In fact, as demonstrated by the simulation, canopied roads with only intermittent open areas (commonly found in "mixed terrain" such as Poland, Germany, and Virginia – except along superhighway corridors) are difficult terrain to engage targets. Predicting future target location is further complicated when, as shown in Figure G-2, there are multiple minor roads that can be used and the attacker has enough time to use only some of them. If targets are detected in one open area, then it is unclear where they will be later. A particularly serious problem was the enemy's movement pattern with small platoon- and company-sized "packets" widely separated in space and time. This resulted in there being only a few "good" targets in open areas even in those instances in which there were any targets at all, seen in Figure G-3. Only a small fraction of the vehicles were armored vehicles, which represented yet another natural "countermeasure." If the projected arrival time of packets in the next open area was only modestly in error, a likely result would be no targets at all rather than just another segment of a uniform column. Further, as Figure G-3 also indicates, an arriving weapon that detected a target in the open might find that its target moved into foliage before it could be struck. That is, the time from detection to impact was in some cases comparable to the transit time across the open area. Large-footprint weapons do not solve this problem.

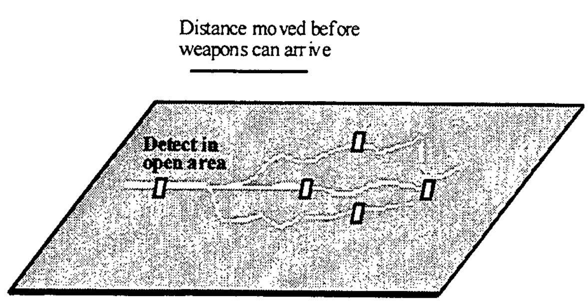

Figure G-2. Intermittent Visibility in Canopied Terrain

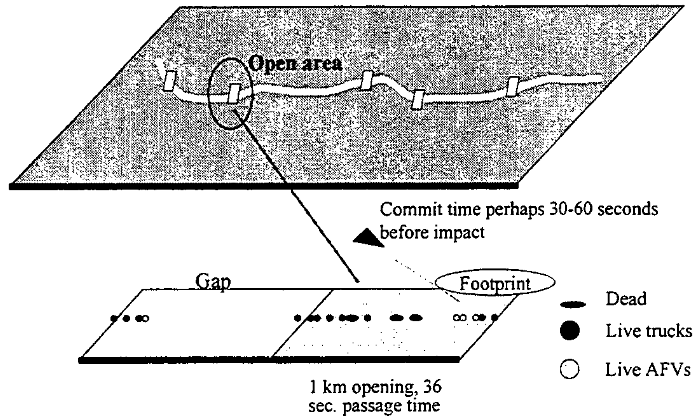

Figure G-3. Movement by Widely Spaced "Packets" Interacts With Terrain Masking

Figure G-4 illustrates yet another problem. "Brilliant weapons" need to infer the appropriate laydown of their submunitions from multiple vehicle detections. However, if they use an algorithm that lays the submunitions along the centroid, that will be the worst possible choice if the dispersion of targets is due to simple road crossing, which is common in open areas in mixed terrain. As for simply "barraging" open areas with fire, there are several problems. The limited number of weapons available would necessarily require limiting the barrage to times when vehicles might reasonably be present. Equally important dead targets would build up in the area and compete with live targets for weapons, resulting in a rapidly diminishing return for additional shots expended, illustrated in Figure G-5.

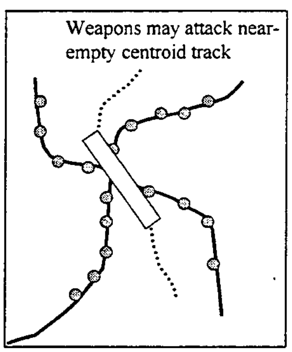

Figure G-4. Brilliant Weapons Are Sometimes Fooled

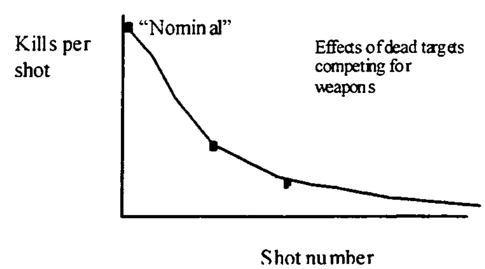

Figure G-5. Dead Targets in an Open Area Can Result in Rapidly Diminishing Returns

Although the analysis was merely illustrative, the outcomes were a sensitive function of many assumptions that need to be examined in lower-resolution work reflecting insights from high-resolution experiments. In addition, detailed analysis of precisely how much each of the above factors contributed to specific-case outcomes would require weeks of post processing. However, several early conclusions are suggested:

- The United States needs to invest in foliage penetrating synthetic aperature radar (SAR) with a GMTI capability to enable detection, identification, and tracking of military relevant targets. Also, new weapons able to survive foliage penetration and properly fuze need to be developed.

- Expectations for the effectiveness of first-generation, long-range fires in mixed terrain against dispersed attacking forces should be low. Non-loitering aircraft could have even more difficult problems if the attacking forces use unpredictable "dash tactics."
- Increasingly good RSTA and shorter decision times would be useful but might be much less effective than expected, especially for long-flight-time missile systems. That is, improving effectiveness for the detection-through-launch portions of Figure G-6 could have disappointing effects in mixed terrain against an enemy deploying in packets because of problems predicting arrival time in open areas and killing them before targets traverse the open areas, as shown in Figure G-3.
- In examining options for more advanced long-range fires, there seems to be substantial value in short time-of-flight systems such as might be carried on a high-altitude, long-endurance "arsenal" UAV.
- For circumstances such as those studied, there would also be value in having "direct-fire" weapons in the sense of one-weapon-one-target, because the good targets are a small fraction of the whole (making expensive area-fire weapons inefficient), and because such weapons can be faster from final commitment to impact (that is, T_{last} in Figure G-6 would be small).
- Improved weapon logic is needed for area weapons used against targets in track-crossing patterns, which may be common in the open areas of mixed-terrain regions.
- Employing land mines in open areas may be a tactic that slows and confuses the enemy "packets" as they try to advance.

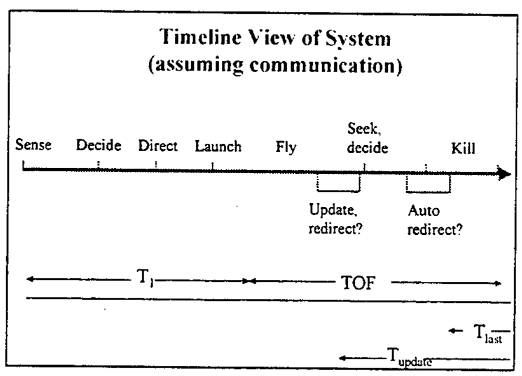

Figure G-6. Relevant Time Scales

Much more analysis is needed before more definitive conclusions can be drawn, but some speculative observations are appropriate. In particular:

- Providing for the update of long-time-of-flight missiles (a widely discussed option within the 1996 and 1998 summer studies) is not necessarily adequate: in mixed terrain, there may be no tracking opportunities between open spots even if the missiles could accept the information unless the United States develops both air- and space-based FOPEN SARs with GMTI.

- Not all loitering platforms of the sort discussed in the summer study are equal. Because of the dash problem alluded to earlier, increasing aircraft loiter time from minutes to tens of minutes or even a few hours might or might not be adequate, depending on the number of platforms. In contrast, long-loiter platforms such as future arsenal aircraft or armed high-altitude, long-endurance UAVs might be more effective. Inserting missile-in-a-box packets might work well (see also discussion in Matsumura, et al.).
- Loitering platforms with a mix of area weapons for moving targets and both area and point weapons for stationary targets have significant advantages.
- Even loitering platforms with "slow weapons" would have problems because some of the detected targets would move out of the open before being killed.
- It is plausible that even moderate FOPEN would prove quite helpful, especially if the weapons used could penetrate foliage and still be effective.
- Because of the potentially small size of target packets, loitering platforms would need to be able to remain in place and survive for quite some time.
- Currently planned product-improvement measures for US long-range fires and RSTA systems are unlikely to solve the problems identified in this analysis, but those and a variety of tactical measures might be very useful. For example, air- or missile-deployed mines might be quite useful in creating choke points, slowing movement generally, and increasing predictability of enemy movements. Visual detections by small ground units able to observe enemy movement through canopied areas could also improve predictability. Neither of these was simulated in the current work.

No firm conclusions should be drawn on these matters without substantially more analysis – both high-resolution work to clarify physical and other phenomena, and lower-resolution work to cut across many of the variables quickly.

HIGH-RESOLUTION INSIGHTS OF COMBINED USE OF LONG-RANGE FIRES AND SMALL MANEUVER FORCES WITH ORGANIC FIRES FOR AMBUSH

An important part of the RAND study was to examine the potential for using dispersed maneuver forces organized in small units in addition to the long-range fires. For the current scenario involving mixed terrain, it was evident that if such forces can be inserted and extracted successfully, they could have a substantial effect on outcomes. RSTA, however, is essential. In this case, what matters is not having "fire-control-quality" extremely capable RSTA, but rather having reliable situational understanding and some ability to project. In the gaming portion of the simulation, the "commander" found improved RSTA assets quite important in providing assurance that enemy forces were not and would not yet be located where he planned to insert his own units. In addition, the commander was able to identify good locations for the purposes of both ambushing enemy units and extracting friendly units.

The analysis considered a variety of ways to employ early-arriving light forces in "offensive" operations in the enemy's rear. They were: (1) inserting a small, highly lethal, but low-mobility

unit where it could potentially block and distract; (2) distributing small but agile units that would ambush a key reserve regiment moving to the front; and (3) distributing small but agile units that would ambush support forces ranging from combat-service support to soft rear-area targets (discussed but not actually simulated). The agile units examined were quite consistent with the agile, light-infantry-response (LIR) forces, but were more specifically based on concepts developed by the Office of the Assistant Secretary of the Army for Research, Development and Acquisition. They were thought to be broadly representative of many concepts being examined by the Marines and Army.

With some repetition, the most important conclusions were these:

- Excellent intelligence preparation of the battlefield and sufficiently comprehensive RSTA were very important in identifying good insertion locations, entry routes, and egress routes. This was gamed rather than simulated, but the human commander needed such information.
- For the scenario played (based on intelligence-community inputs), the enemy's air defenses were substantial and threatening. They were netted and included mobile systems (SA-12s). As a result, insertion into the rear would have been very difficult. For this analysis, and in light of the many ongoing studies on SEAD, the SEAD operation's success was *assumed*. However, analysis also suggested an alternative concept of operations, which would be to insert units before the enemy's forces arrived in an area ("anticipatory insertion"), allowing the enemy forces to move through the area before ambushing would begin. The forces could also be inserted if they were reinforcing coalition forces' main-defense units rather than going deep into the enemy's rear.
- The relatively static insertion force was quite capable (it incorporated the kinds of short-range precision, indirect-fire measures studied in recent years for the future 82nd airborne), but its effectiveness was questionable because of the enemy's ability to bypass it. Also, survivability was a serious issue.
- The more agile insertion forces appeared to constitute a very attractive concept. Their distributed operation and tactical mobility greatly increased apparent survivability and, in simulation, they were quite successful in ambushing enemy forces. Because of current simulation limitations they were played as attacking combat-service support vehicles and combat units, which might be much riskier and less effective than attacking more static and less well protected rear-area support structures as envisioned in various Marine and Army studies. Still, in the simulation at least, the agile force did well even against the more difficult targets. Attacks on softer targets (not simulated) might have done even better if one considers the likely and possible effects of disruption – effects strongly emphasized by senior ground-force operators. Thus, the results tend to corroborate the future tactics being pursued by the Marines and elements of the Army – albeit with many caveats.
- Most important, <u>the combination of long-range fires and agile insertion forces were successful in their simulated attacks, while long-range forces alone would not have been (for the circumstances of the scenario examined)</u>. Further, gaming and discussion suggested that in the real world there would have been numerous synergies that were not fully simulated in this first effort. In particular: (1) ground-force

ambushes could create log jams and delays and could cause the enemy to concentrate force more (whether or not wisely), improving target density and providing more time for long-range fires to operate; (2) ground-force ambushes could be seriously disruptive, causing the attacking commander to delay movement and divert forces to protect against ambush and track down his attackers; (3) ground units could, with both "eyeballs" and organic RSTA (including locally controlled UAVs or acoustic sensors), greatly improve the ability to predict when good target vehicles would be entering open target areas; and (4) long-range fires would be a very important element in making maneuver operations even feasible, as well as a major independent source of attrition.

Figure G-7 shows results from a number of high-resolution man-in-the-loop simulations. It focuses on the case of near-perfect RSTA with short command and control delays (but not continuous fire-control-quality RSTA for long-range fires). For each pair of bargraphs, the left one shows Red losses and the right shows Blue losses. Case 3 shows results if the maneuver units engaged a key regiment in the rear area and Case 4 shows the same agile maneuver units attacking supporting units. For Case 4 the figure also shows how those attacks might have a disruptive effect "equivalent" to that caused by direct attrition to a given regiment. Although speculative, this is the type of effect that experienced commanders tend to believe have high payoff.

Rather generally, the strengths and weaknesses of long-range fires and maneuver units tended to be complementary. Although the operational environment studied was highly specific and many uncertainties exist, the analysis strongly suggested that the combination of long-range fires and agile ground-force units could be very powerful for future joint task force commanders.

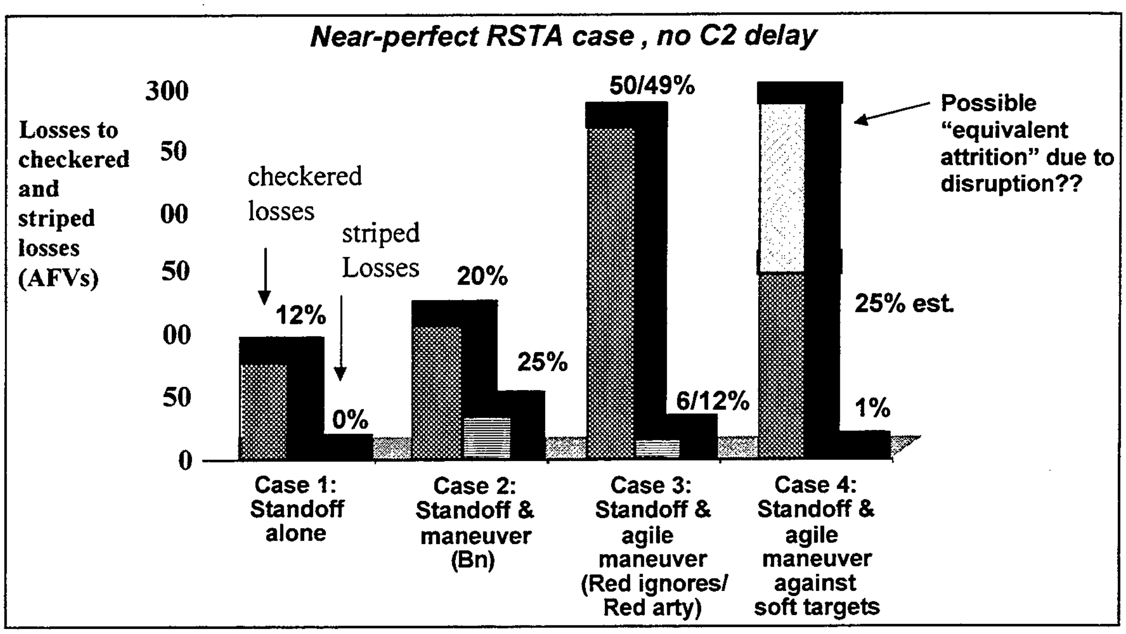

Figure G-7. Results of Simulation and Gaming: Standoff Attack with Ground-Force Maneuver Greatly Increases Effectiveness, With Some Losses to Blue

SOME SPECIAL UNCERTAINTIES

Although not addressed in the analysis, several problems merit mention. First, mobile defenses available from the Russians and others will provide some capability against currently programmed precision guided munitions, even TACMS missiles and JSOW. Second, the ability to accomplish SEAD quickly to permit the operation of aircraft and loitering UAVs may not be easy. Third, while stealthy loitering platforms might be survivable if passive, the act of firing weapons might undercut their survivability. With respect to ground units, it is possible that enemy tactics such as sending infantry units ahead to check predicted ambush sites would reduce small-unit survivability significantly. Because of this, the RAND analysis team noted that there may be considerable potential for inserting unmanned "missile-in-box" modules.

WHERE NEXT?

A great deal of in-depth study and analysis is needed to better understand the interplay of measures and countermeasures (both tactical and technical), terrain, and scenario. The analysis accomplished for the DSB 1998 Summer Study should be the beginning, not the end. Even this limited effort demonstrated the value of alternative forms of analysis (high, low, and more focused high-resolution work described in Volume II) – not so much in providing "numbers," but in illuminating basic elements of phenomenology on the one hand, and a broad cross-scenario perspective on the other. To date, however, there has been relatively little effort to convince the various analytic communities to deal with one another and compare results. Nor is this a built-in aspect of the Joint Warfare System and Joint Simulation System programs. As we enter an era of joint experimentation on advanced concepts, even more of this family-of-models work will be essential.[8]

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8 This is a theme of Davis et al., 1998, cited above, and a National Research Council study on modeling and simulation, *Volume 9 of Tactics and Technology for the United States Navy and Marine Corps, 2010-2035*, National Academy Press, 1997.

ANNEX H:

Space Maneuver Vehicle and Common Aero Vehicle

SPACE MANEUVER VEHICLE AND COMMON AERO VEHICLE

The Space Maneuver Vehicle (SMV) is a reusable, unmanned orbiting vehicle with integral propulsion that completes an on-orbit mission and then re-enters the atmosphere and lands for retasking. The SMV's on-orbit maneuverability allows it to change altitude or execute plane changes to access different orbits, thereby greatly increasing its operational flexibility and making it a difficult platform to track. The SMV system can be employed as either a single asset or a constellation to support the warfighter's efforts. When employed to support theater operations, SMVs provide a "visible presence" in and from space and may be recalled at the end of a crisis. Notional Space Maneuver Vehicles are illustrated in Figure H-1.

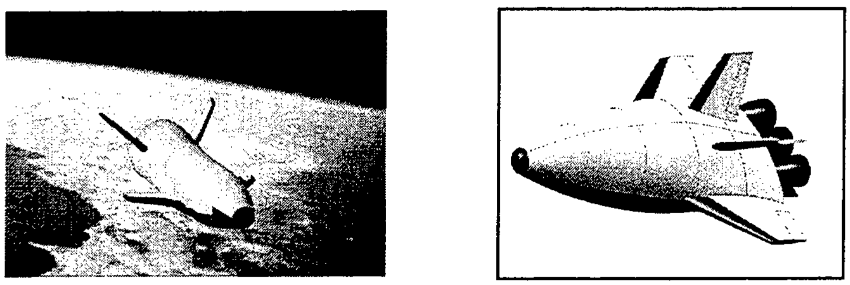


Figure H-1. Notional Space Maneuver Vehicles

The SMV can be launched from numerous vehicles to provide operational flexibility independent of future launch system development. Current planning calls for the SMV to be flight tested from the Space Shuttle and existing expendable launch vehicles (ELV). Once the SMV reaches operational status, additional launch platforms will include ELVs, shown in Figures H-2 and H-3 respectively. In line with current launch policy, some launches of the SMV may be contracted to commercial launch service providers.

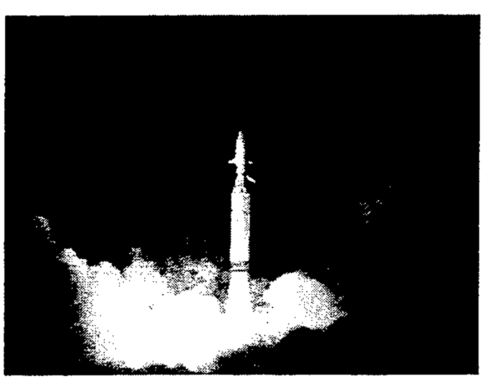


Figure H-2. Notional ELV with SMV Payload

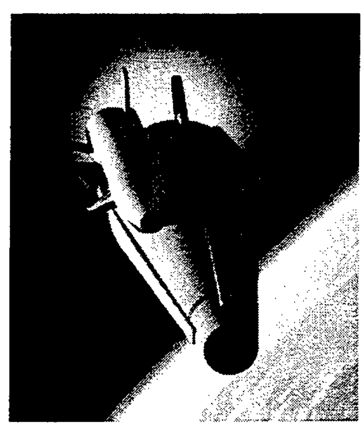


Figure H-3. Notional SOV with External SMV Payload

Sub-Orbital Delivery. The SMV can be launched by a booster unable to achieve orbit, such as ELVs and sub-orbital space operations vehicle (SOVs). The SMV can be carried internally by a launcher – such as a pop-up out of a sub-orbital SOV payload bay for example – stacked on top of an expendable vehicle or mounted piggy-back on a sub-orbital SOV. In the sub-orbital configuration, the SMV serves as an upper stage by using its own onboard propulsion to provide the final boost to orbit. This delivery method supports missions that do not require extensive on-orbit maneuvering capability, such as being deployed in a fixed constellation.

Orbital Delivery. In an orbital delivery, the launch system provides all the lift necessary to insert the SMV into orbit. Depending on the launch vehicle type, the SMV can be carried externally or internally within a payload bay. An orbital delivery allows a fully fueled SMV to use its onboard propulsion to execute a variety of space maneuvers to include larger altitude and plane changes, geosynchronous Earth orbit (GEO) flybys, or co-orbital station keeping with satellites in medium Earth orbit (MEO) and low Earth orbit (LEO).

SMV Missions

Mission Overview

The SMV will support a wide range of operational missions, from performing reconnaissance and space control missions to servicing other satellites while on-orbit. The responsiveness and affordability of the launch systems used will enhance the overall effectiveness and efficiency of the SMV system. Just as the airplane's military role began solely as a reconnaissance platform and evolved to perform many types of missions based on different payloads, the SMV represents the next step in the evolution of space systems by providing an orbital vehicle capable of performing multiple missions.

The SMV will complement DoD warfighting assets. Its primary attributes are reusability, affordable cost, global coverage, responsive orbital agility, orbital endurance for as long as 12 months, and relative invulnerability to enemy defenses. These characteristics will allow the SMV to enhance, expand, and protect existing space assets, and also allow it to perform missions that are beyond the capability of current space systems in a cost-efficient manner.

Taken together, the unique and enabling capabilities of the SMV will be critical to protecting US military, civil, and commercial space assets and providing the National Command Authorities and Joint Force Commander the required flexible and survivable capabilities needed for dynamic crisis and battle management.

Space Control

The SMV can fill vital needs in space control which current systems are unable to meet. By providing a highly maneuverable space platform for both offensive and defensive counter space payloads, space superiority can be achieved. Protecting valuable military, civil, and commercial space assets from potential adversaries and denying the use of adversarial space assets will assure our access of space and meet the objectives of space control.

Once deployed by the launch vehicle, an SMV's payload can perform defensive counter space missions by jamming or blocking hostile space systems. As commercial and military

systems evolve to rely more heavily on space-based systems, defensive counter space activities must expand and evolve to provide enhanced on-orbit resource protection.

Because US and foreign military space systems are predominantly information systems, achieving space superiority will involve offensive and defensive information operations. SMV and its payloads have great potential to contribute to information operations in space. In addition to jamming or degrading an adversary's space system, an SMV payload could possibly spoof their sensors to achieve deception or could electronically disable their systems.

SMV's multi-mission capabilities could play a key role in establishing and maintaining future national missile defense and theater missile defense systems. Small elements of a missile defense system could be delivered, deployed, repositioned, or recovered by the SMV. SMVs could service permanent elements of a missile defense system through on-orbit refueling or repair. On-board payloads, or payloads deployed from the SMV, could provide short-notice gap-filler capability for a missile defense system until it is restored to full capability, and the SMV can then recover the temporary asset for refurbishment and reuse.

By performing space surveillance, sensors deployed from the SMV or operated onboard as a suite can complement and enhance existing ground-based systems for tracking satellites and identifying their capabilities. Through its ability to perform fly-bys of other satellites, the SMV will markedly improve US Space Object Identification (SOI) capabilities to catalog other nations' space forces. Microsats deployed from the SMV can complement and enhance existing ground-based systems through their ability to perform autonomous proximity operations to deliver very high-resolution SOI data. This space surveillance capability will also provide increased coverage and resolution for space debris detection and warning for friendly assets.

Force Enhancement

Force enhancement operations are conducted from space with the objective of enabling or supporting terrestrial forces. Navigation, communications, reconnaissance, surveillance, and environmental sensing help reduce uncertainty and friction at all levels of war.

The SMV will be capable of using onboard surveillance and reconnaissance suites during over flight of an area of interest to help provide intelligence information essential to the "transparency" envisioned in Joint Vision 2010 for battle planning and strategy development. The SMV's rapid response gives theater Commanders-in-Chiefs a major advantage early in a conflict before other platforms arrive. Major assistance to the theater will be possible through the ability to deliver and deploy a large number of surveillance and reconnaissance configured SMVs to LEO. These SMVs can be flown to create an independent intelligence, surveillance, and reconnaissance (ISR) constellation, or they could augment existing ISR constellations to improve coverage over particular areas of interest.

The SMV can also deploy payloads to augment communications in areas where coverage is degraded or missing due to a communication system failure. The SMV's rapid retasking capability, along with its standoff and real-time downlink ability, make it well suited for ad hoc tasking that meets the challenge of a rapidly changing battlefield situation. Employing SMVs will provide a quantum leap in maneuvering flexibility for ISR payloads beyond that found in orbital systems today. Unlike current space systems, which are limited in their ability to change orbits, SMVs with onboard ISR payloads can respond to emerging requirements and threats by

performing critical orbit inclination changes. This enables multiple target overflight opportunities, decreased revisit times, and quick response to retaskings. In essence, the SMV will be capable of complementing or replacing traditional airborne ISR platforms with a continuous, on-demand theater-wide system that is more flexible, responsive, and survivable.

Force Support

Force support must sustain operations if air and space forces are to be successful. The SMV will be the first space vehicle designed to support on-orbit servicing of military space-based assets, such as space-based lasers and small satellites. The SMV can perform the necessary on-orbit maneuvers to rendezvous, refuel, upgrade, repair, and possibly reposition or recover space assets. This will include the capability to co-orbit with and assess damage to friendly space-based platforms, thereby providing support for anomaly resolution.

The SMV will complement dedicated spacelift assets by providing rapid response and low-cost deployment of small satellites. Its quick turnaround, high sortie rates, and capability to deploy and recover multiple small satellites will provide the United States with a flexible, on-demand space presence.

Space Test

The SMV can also be used as a space test platform similar to the way F-15s are used to experiment with new aircraft subsystems and payloads. The SMV will allow rapid technology demonstration and insertion of new space-based capabilities that meet unanticipated threats. This can be accomplished in conjunction with planned operational missions, thus allowing full asset utilization. The SMV's ability to return to Earth gives the space test community a capability to recover test articles for analysis and reuse. Additionally, the SMV can be used to enhance the operational security of a testing activity by preventing hostile SOI activities on the test payload.

Employment Profiles

The SMV system will provide total global access, from LEO to geosynchronous orbits and will be employed in one of two ways: 1) as an individually controlled platform where only one SMV is needed or the mission requires direct operator control; and 2) as multiple SMVs that make up a constellation and are controlled as a group by a single operator team.

The *individual mission profile*, shown in Figure H-4, allows one operator team to manage the SMV during its mission. This profile is used when a high degree of interaction is required between the operator team and the vehicle. Missions such as on-orbit servicing and refueling and missions that may require multiple orbital maneuvers will use the individual mission profile.

The *constellation profile*, shown in Figure H-5, takes advantage of the orbital similarities of the mission and allows one operator team to manage multiple SMVs at the same time. This profile is used when the majority of the mission can be automated and the operators only manage the anomalies. Missions such as communication or ISR augmentation can be achieved without having to "fly" each satellite as an individual platform.

Figure H-4. Individual Mission Profile

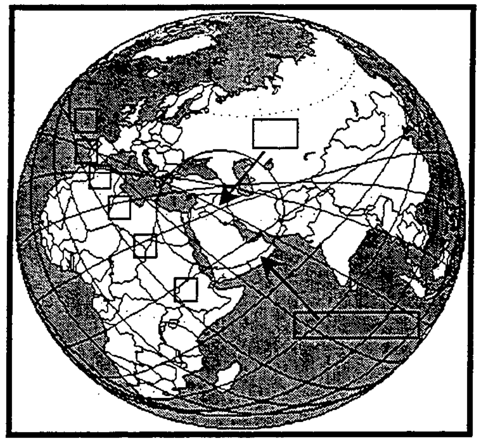


Figure H-5. Constellation Profile

SMV Development Roadmap

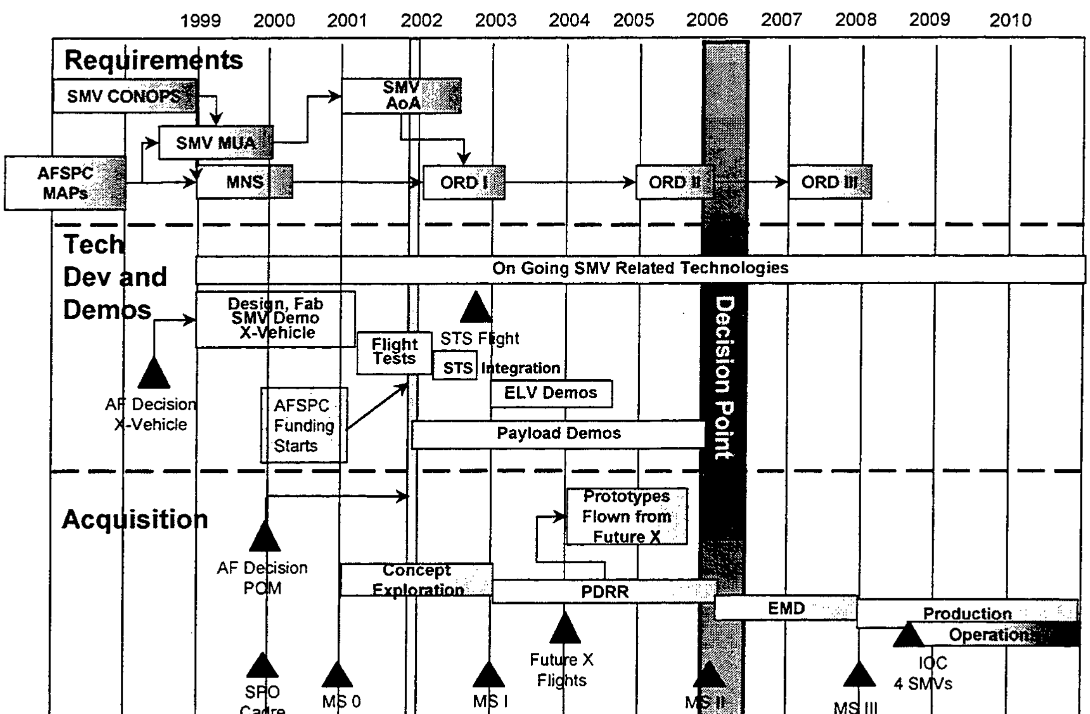


Figure H-6. SMV Roadmap

The Air Force, with technical support from NASA, will lead the development of the SMV. NASA has expressed interest in possible uses of a civil version for International Space Station support, and has indicated a willingness to provide a Shuttle flight for on-orbit testing of an SMV demonstrator. Air Force development and flight test of an SMV demonstrator vehicle, the X-40,

vehicle, the X-40, deploying an experimental or operational payload, will precede any programmatic decision for the full-scale development of an operational SMV.

DoD and NASA have formed a "Partnership of Commitment" to coordinate and combine research and development of shared technology and systems. Funding and progress of this "family of systems" will be integrally developed and coordinated between organizations within the planning, programming, and budgeting system cycles. Current plans for a shuttle demo flight in 2002 are shown in Figure H-6.

COMMON AERO VEHICLE

As part of development for the SOV, Air Force Space Command is leading an initiative to explore a Common Aero Vehicle (CAV) concept to provide capability to deliver a force application mission payload from the SOV. Initial capability could be deployed on ballistic missiles until transition to the SOV.

The CAV – a modified maneuverable reentry vehicle shown in Figure H-7 – will provide a delivery platform for multiple mission assets from and through space, as well as a testbed for various experiments requiring highly stressful flight dynamics. Possible demonstrations include delivery of conventional munitions against notional military targets at the Kwajalein Atolls Test Range. It could target a variety of fixed and relocatable targets as well as hard and deeply buried targets. Initial capabilities will address the hard and deeply buried target defeat capability and the ability to destroy weapons of mass destruction facilities.

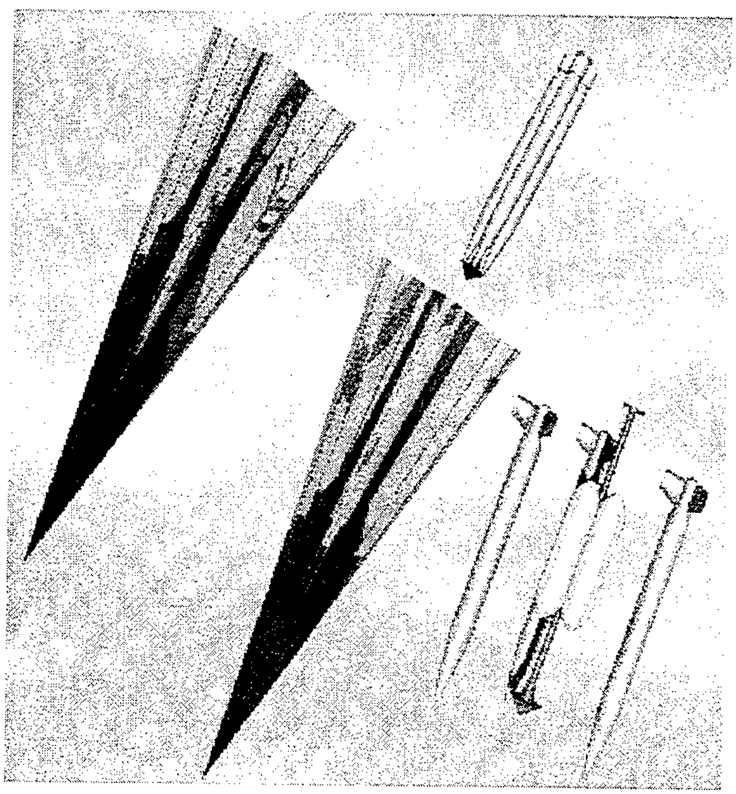


Figure H-7. Common Aero Vehicle

Low development costs can be achieved by using concepts previously designed for the ICBM fleet but never fielded. The initial SOV capability (most likely sub-orbital) will require some modification to existing concepts.

The CAV is an evolution of the High-Speed Precision Penetrator ACTD with greater footprint coverage. Advanced munitions provide greatly increased capabilities against numerous deficiencies identified in various command's mission area plans.

The CAV/ballistic missile demonstrator could fly as early as the 2003 timeframe with initial program cost estimates of \$75M - \$150M. Further refinement of program costs and trade-offs are ongoing. A 24-36 month effort would include two short-range test launches at White Sands Missile Range, one test launch from Vandenberg AFB to Kwajalein Atoll, and one fully operational spare. Concept of operations includes the application of a maneuverable reentry vehicle delivering munitions now under development for the F-22 and Joint Strike Fighter. Specific weapons may include Single Unitary Penetrators, the Small Bomb System and the LOCAAS.

This demonstration is the first step in the implementation of the Aerospace Expeditionary Force of the 21st-century and the Air Force vision of global engagement.

ANNEX I:

Applying Chaos and Complexity Theories to Command and Control and Combat Operations

APPLYING CHAOS AND COMPLEXITY THEORIES TO COMMAND AND CONTROL AND COMBAT OPERATIONS

DESCRIPTION AND RATIONALE

Concepts, tools, and general methodologies derived from quantum physics, nonlinear dynamics, and chaos and complexity theories offer enormous potential for studying and resolving military and defense-related problems. Until the advent of the modern computer, researchers were unable to examine nonlinear phenomena in any depth. This was certainly the case for warfare since combat is inherently nonlinear. As one analyst notes, military conflict has all the features of complex adaptive systems. In particular, combat units are composed of large numbers of nonlinearly interacting parts; local action which often appears disordered, over time produces order; battles and engagement move far from equilibrium; and military units continuously adapt to a changing environment.[1] Table I-1 matches the generic properties of complex adaptive systems to key attributes of combat forces and actions.

Table I-1. Complex Adaptive Systems and Combat[2]

Generic Property of Complex Adaptive Systems	Description of Relevance to Combat
Nonlinear interaction	Combat forces composed of a large number of nonlinearly interacting parts; sources include feedback loops in C^2 hierarchy, interpretation of (and adaptation to), enemy actions, decision making process, and elements of chance
Nonreductionist	Overall "fighting ability" of a combat force is not a simple aggregate function of fighting ability of individual combatants
Hierarchical structure	Combat forces organized in a command and control hierarchy
Decentralized control	No master "oracle" dictating actions of each and every combatant
Self-organization	Local actions, which often appears chaotic, induce long-range order
Nonequilibrium order	Military conflicts by their nature, proceed far from equilibrium
Adaptation	To survive, combat forces continually adapt to a changing environment
Collectivist dynamics	A continual feedback between behavior of (low-level) combatants and (high-level) command structure

[1] Illachinski, Andrew, *Land Warfare and Complexity Part II: An Assessment of Nonlinear Dynamics and Complex Systems to the Study of Land Warfare*, (Center for Naval Analyses, Alexandria, Virginia, July 1996), p.2.
[2] Ibid, p.2 (adapted from original).

Computer-supported research, coupled with other ongoing studies, is producing a deeper understanding of nonlinear systems. These efforts are also producing tools that could be enormously useful to the military. Examples are genetic algorithms, tactical picture agents, fractal-based image compression, determinative-based cryptography, and adaptive dynamic combat models. These and other tools could be used to "breed" tactical concepts or software for warheads, create combat aids – especially in the area of command and control – test the veracity of conventional models, improve or replace Lanchester's equations, and extract patterns from historical data.

FORCE CHARACTERISTIC IMPLICATIONS

Successful application of the ideas and tools of nonlinear dynamics would have profound effects on future military doctrine, organization, training, and equipment. The mechanistic flavor in much of current doctrine would be replaced by a less restrictive decentralized approach. Organizations would have a less hierarchial look and could appear more like a neural net. Training would be supported by models and simulations that are no longer linear and deterministic, thus they would more closely replicate real-world behavior. Weapons and equipment would be designed using genetic or evolutionary algorithms and incorporate adaptive agents and cellular automata.

ENABLING TECHNOLOGIES

- Research in the areas of nonlinearity, deterministic chaos, complexity, self-organization, and emergence.
- Developing genetic algorithm-based tools such as "Active Nonlinear Test".
- Exploiting the implications of nonlinear dynamics in modifying or replacing Lanchester equations.
- Examining historical data from past conflicts to find evidence of self-organized criticality.
- Creating image compression tools such as the "Iterated Function System" developed at the Georgia Institute of Technology.
- Developing genetic and evolutionary algorithms that could be used to "breed" or "evolve" weapons and tactics.
- Developing full system models that are cellular- automata- and multi-agent-based.

MAJOR UNCERTAINTIES

Though a number of research efforts are ongoing in the areas of nonlinear dynamics and chaos and complexity theories, few are oriented toward solving military-related problems. A more focused approach is needed if current research is to be effective. Moreover, additional resources will have to be devoted to research if significant results are to be achieved in the near term. Organizations that currently support studies in nonlinear dynamics and chaos and

complexity studies are the Santa Fe Institute, George Mason University, the Office of Naval Research, and the Center for Naval Analyses. Ongoing and future studies and research will have to be successful in order for useful tools to be produced.

ANNEX J:

Sensor Systems

SENSOR SYSTEMS

Joint Vision 2010 envisions a future in which American military operations are conducted across a broad spectrum of conflicts and environments with near-instantaneous surge, highly synchronized precision fires, and relatively small units. Underlying this vision is an explicit assumption that US forces will have comprehensive, real time information about the enemy's environment, actions, and intentions. This annex elaborates on Chapter 4's discussion of the adequacy of current technology for achieving comprehensive knowledge about the battlespace.

COMPREHENSIVE REAL-TIME BATTLESPACE AWARENESS IN TECHNICAL TERMS

In addition to an information infrastructure, discussed in Chapter 4 and Annex K, there are three top-level components in a system of systems for comprehensive, real-time battlespace awareness.

- *Sensors that "see everything all the time."* This means sensors that see objects or behaviors of interest whether stationary or moving, whether in the open or obscured by foliage, terrain, or urban structures, and regardless of how far-flung. Anything less is simply not "comprehensive" and runs the risk of missing things of value to the enemy and/or lethal to friendly forces.
- Algorithms, processors, and visualization strategies for automatically reducing sensor information into manageable proportions.
- *Scaleable sensor management technique.* "Seeing everything all the time" implies many sensors of different types, which in turn implies a potential for severe redundancy and/or many ways for any particular information request to get satisfied. Sensor management must be responsive, in real time, to new intelligence or urgent changes in commanders' guidance. In addition, there is a real and frequent need to bring more than one sensor to bear at the same time on a given piece of the battlespace.

ORGANIZATION, POLICY

Intelligence, surveillance, and reconnaissance (ISR) as implied by Joint Vision 2010 requires designing and integrating a dramatically more complex and less stovepiped system-of systems than is in place today. Such design and integration is taking place only in part, if at all.

ISR complexity is apparent from the references above to sensors that "see everything," to real time retasking of numerous and far-flung sensors, and to real-time user access to data from sensors unrestricted by geography, phenomenology, or ownership. These are all dramatically different from ISR as practiced in DoD today.[1] Within DoD, high-level planning of an integrated ISR system of systems is only beginning, and the current ASD (C^3I) focus on

[1] DoD may find it useful to examine the Brazilian government's SIVAM project for comprehensive surveillance of the Amazon.

communications and interface standards has yet to encompass sensors, exploitation, and sensor management. Moreover, a number of important issues are not adequately taken into account in the current policy and planning forum. There is an informed awareness of critical advanced technologies such as ATR or high-resolution GMTI. System architecture tends to be equated with inter-entity "wiring diagrams," without regard for actual sensor/processing capabilities, or for the essential dynamism of sensor management. Architecture is essentially a technical activity ("technical" can refer either to sensors or to war fighting), while "wiring diagrams" are bureaucratic – poor substitutes that do not guide deep operational trades, let alone strategy. The present state of affairs exhibits the disconnect between the planning, operational, and technological communities. This isolation is incompatible with the creation of a large-scale system-of-systems. In addition, more attention needs to be paid to the real-time characterization of space – the proliferation of foreign and commercial space-based communications and sensing capabilities.

SENSORS

The current investment in remote sensing emphasizes wide-area radar imaging and moving-target indication and short-exposure electro-optic imaging of focused areas. Investment in local sensing emphasizes unattended ground sensors for seeing "around the next corner" or "into the next building," at best. These are crucial capabilities, but, as Figures J-1 and J-2 illustrate, they leave important gaps with respect to Joint Vision 2010's "full spectrum" of conflict. High-frequency radar – SAR and GMTI – penetrates weather and can sense wide areas, but can't see past obstacles, such as into cities. Low-frequency radar can at least penetrate foliage, at the expense of reduced-area coverage, but still cannot see past terrain obstacles, let alone into cities. In any event, foliage-penetrating GMTI has never been demonstrated, only SAR. Electro-optic remote sensing is much less vulnerable to complex terrain, since it can look straight down; but it is very vulnerable to clouds and foliage; and electro-optic GMTI has never been demonstrated. Local sensors such as unattended ground sensors (UGS) or micro air vehicles can in principle sense into nooks and crannies completely off-limits to remote sensing, regardless of weather, but without special measures, such as very aggressive dispersal combined with very aggressive internetting, their output is anything but "comprehensive." Further what is really needed are mobile, dynamically tasked unattended sensor systems, not static UGSs.

SENSOR EXPLOITATION

The task force is encouraged that ATR techniques are making their way into demonstration systems for exploiting wide-area high-frequency SAR imagery. However, ATR for other search sensors or modes is not as far along, and for some sensors remains in an early state. (This includes visible and infrared imagery, where contrast looking down is problematic, as well as hyperspectral imaging.) Ongoing activities in ATR and sensor fusion are essential to Joint Vision 2010, but need to keep pace with the increased sensor richness that Joint Vision 2010 implies.

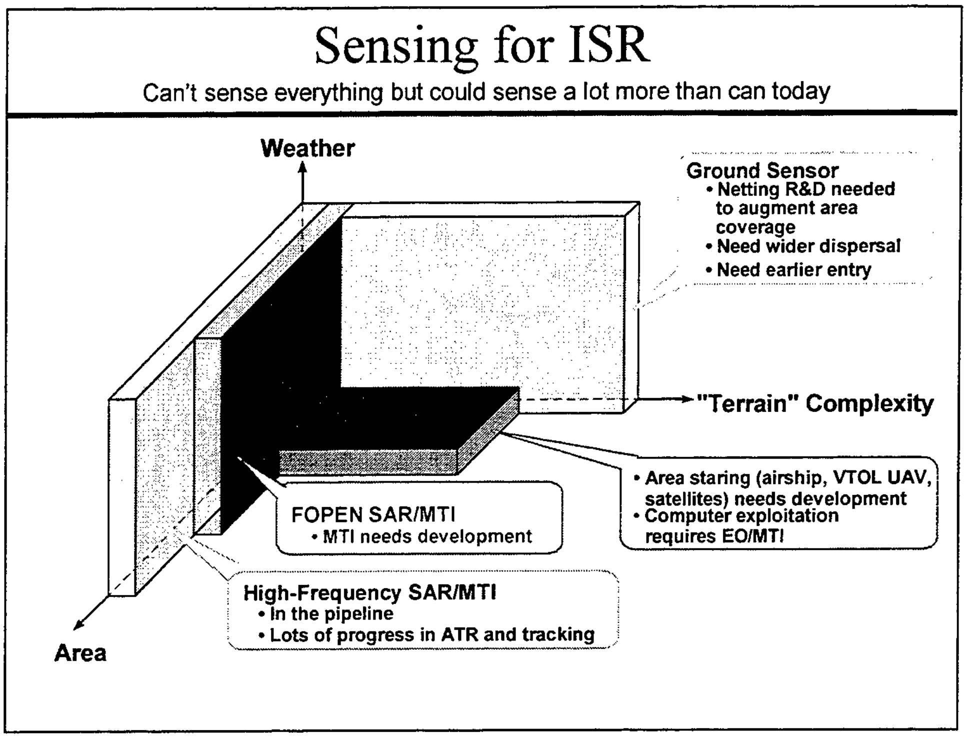


Figure J-1. Sensing for ISR

Sensing for ISR

Can't sense everything but could sense a lot more than can today

Sensor Type	All Weather	Area Coverage	Terrain Complexity	Sense Movers	Recommendations / Challenge
High-frequency radar	Yes	Wide	Benign	Yes, but high-resolution GMTI not widespread	Push high-resolution GMTI
Low-frequency radar	Yes	Moderate	Benign, plus foliage	In principle	Develop FOPEN GMTI - Space - Airborne
Remote EO	No	Moderate	Anything outdoor if looking down	In principle, but staring focal planes and moving target filtering needed	Push down-looking, staring focal plane arrays with moving-target filtering
UGS, Micro UAVs, etc.	Yes	Narrow, but could be wider dispersal and aggressive internetting	Outdoor, indoors	Yes	Push to widen area scope of small sensors by multiplicity, dispersal, networking, and mobility

Figure J-2. Sensing for ISR

Joint Vision 2010 requires a capability – sensors, algorithms, and infrastructure – to track moving ground targets continuously. This is important for two reasons. First, precision fire against moving targets necessitates an ability to track them between initial detection and the time of weapon delivery. Second, intelligence "detective work" plays a role in determining, for example, the weapons of mass destruction infrastructure, by being able to use information such as vehicular traffic and shipments to "connect the dots" between suspected facilities. Either capability requires robust, long-duration tracks. This finding has implications for sensor management and data communications as well as processing.

Sensor Management

Increased progress in sensor management is needed to keep pace with the growing needs for surveillance responsiveness and sensor richness implied by Joint Vision 2010. More focused research and development in sensor management should address the challenge of real-time retasking, as necessitated by prosecution of "perishable" targets such as TELs. Additional research and development is needed to confront the computational complexity of sensor management software when the number of sensors to be managed becomes large.

Recommendations

Recommendations for development of advanced sensors, exploitation, and sensor management are discussed in the Sensor Systems section of Chapter 4. The key recommendation is to develop a comprehensive ISR operational architecture that covers sensors, exploitation, tasking, and information management in addition to communications and interface standards that integrate ground, air, and space systems.

To develop such an architecture, quantitative operational trades should be initiated taking full and realistic account of current technical performance expectations such as detection and false-alarm probabilities, area rates, slew rates, minimum detectable velocities, and countermeasures, for example. Such trades should take the form of analyses from fundamental principles, and engagement-level simulations should be upgraded to take new and emerging technologies into account. The operational architecture team should also identify and conduct experiments to illuminate critical operational issues, such as how an adversary can evade different levels of US remote sensing and still function effectively. The operational architecture team should also begin to derive and enforce technical standards that address the critical needs of key technologies for the future. Examples include standardization of GMTI data formats and promulgation of requirements for complex SAR imagery that are essential for super resolution.

These suggestions require coupling between the operational, planning, and technological communities within DoD and industry. They are the necessary first steps toward a national commitment to making real-time, integrated ISR a national priority with a credible timetable. Such a commitment is nothing less than a necessary condition for underwriting Joint Vision 2010.

ANNEX K:

Integrated Information Infrastructure

THE INTEGRATED INFORMATION INFRASTRUCTURE

Chapter 3 introduced the concept and structure for an Integrated Information Infrastructure. This Annex elaborates on that vision by providing a high-level perspective of several of the structure's layers, describing a detailed implementation strategy, and assigning responsibility within DoD for carrying out this strategy.

THE INFORMATION INFRASTRUCTURE: TRANSPORT LAYER

GLOBAL CONNECTIVITY

The transport layer of the infrastructure consists of four tiers. These tiers are conceptual, because the interfaces between them are seamless and transparent to the user – tiering serves only to relate the information infrastructure to organizational and doctrinal concepts, as shown in Figure K-1. In fact, any entity in the information infrastructure can virtually and automatically be connected to and interact with any other entity directly. While such ubiquitous connectivity is likely to be a very powerful force multiplier, traditional organizational and doctrinal constructs are expected to change more slowly than the technology that makes such connectivity possible.

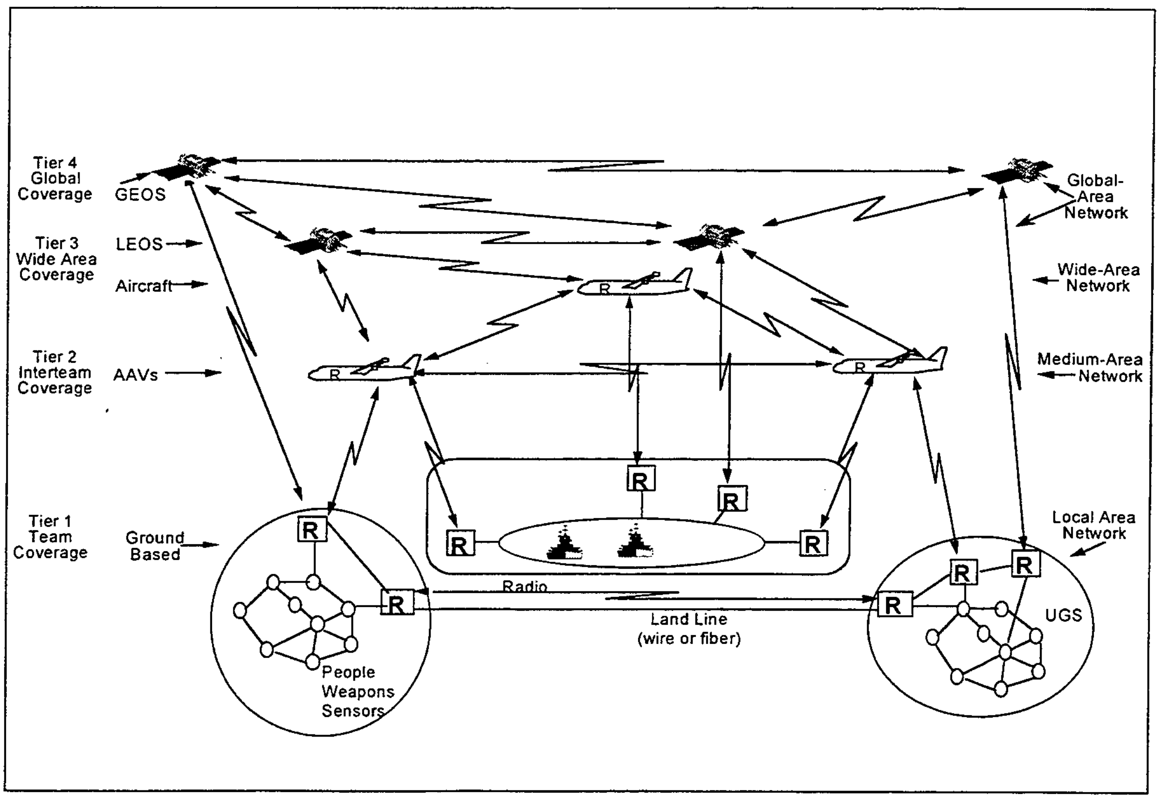


Figure K-1. Information Infrastructure: Tiered Transport

Tier 1

The first tier of the transport layer is the tactical component. This infrastructure component comprises local-area networks that provide voice and data services to entities operating together in integrated or support missions. These transport networks are store-and-forward, packet-switched systems that are self-managed and adaptive and provide peer-to-peer data relay and processing. The networks adapt to changes in the locations (i.e., the mobility) of its end users; they have no centralized nodes or base stations that would enforce the use of a vulnerable star topology; and they automatically route information among participating nodes, based on real-time assessments of the network connectivity. These local-area transport networks can support a single person or a force structure of any size through appropriate subnetting.

Although there are a few modest examples of peer-to-peer, wireless, packet-data communication systems deployed in the private sector, the fundamental work in this type of technology has been and continues to be funded by the Department of Defense (DoD). This trend will likely continue, given that the private sector's present view of ground-based wireless data communications is predicated on the notion of a deployed fixed infrastructure (base stations connected to the wireplant) to which, and through which, each mobile subscriber establishes a communication circuit. This commercial wireless system architecture is based on many years of legacy, point-to-point, voice-based telephony systems. This system architecture also facilitates billing and related revenue generating processes for mobile subscribers.

In contrast, the military has relied primarily on push-to-talk, broadcast, wireless communication systems for its mobile users. This system architecture, however, proves to be severely limiting in regard to supporting highly mobile users; dynamic, flexible force structures; and mission/time varying information transport requirements.

For these reasons, DARPA initiated a packet radio program in the 1970s. This technology-based program was intended to explore the notion of building intelligent radios that would be networked to provide the highly mobile warfighter with data services while on the move. These radios would self-organize into networks, automatically route (relay) information from any source to any destination within the radio network (or across the internetwork to other users), automatically adapt to failed nodes or stress exposed on the network by an adversary, and perform other similar network services. This technology base has resulted in systems such as the Army's Surrogate Data Radio (developed by Hazeltine Corporation[1]) and the Near-Term Data Radio (developed by ITT). However, these systems will not fulfill the vision set for Tier 1 of the Integrated Information Infrastructure. It is the research and development being pursued in the DARPA Small Unit Operations and Global Mobile (GloMo) projects, if appropriately focused and guided, that will lead toward technology that will meet the joint, mobile, warfighter needs. These programs will provide the fundamental knowledge and technology that will meet the network requirements set forth in the Joint Tactical Radio System (JTRS) Operational Requirements Document.

It is anticipated that as these DoD-supported, technology-based programs generate stable technology (specifically, network algorithms and software), these technologies will ultimately be embraced in the private sector, as the need for supporting data and voice services to mobile commercial subscribers manifests itself. This technology transfer to the private sector is,

[1] All product or company names mentioned in this document are the trademarks of their respective holders.

however, not anticipated for many years, and will be driven by consumer demand for flexible, reliable, mobile data services and by high-level interest in internetwork-based mobile data services within the telecommunications industry.

Tier 2

At the second tier, the transport layer incorporates airborne networks and processors for data transport and information services among force entities that require connectivity beyond that supported by their local area network. To support this broader area coverage, we envision a swarm of autonomous air vehicles that support medium-area networking services. These platforms are cross linked with other airborne and space-borne networks, as required, and are linked to the local-area networks.

The private sector is pursuing similar concepts of airborne-relay telecommunication platforms. Two such activities, which are currently raising capital, are the Skystation and Air Relay. The Skystation is conceived to be a station-keeping, lighter-than-air platform located 22 km above the earth. This proposed activity would provide 10 Mbps data services to every home within the service area covered by each platform. The Air Relay, in turn, are intended to be aircraft-based telecommunication relays that provide data services to ground-based users.

In both of these and similar commercial concepts, however, the system architecture (the location of platforms, relaying and switching, and bandwidth allocation) consists of parameters that are predefined and managed through centralized facilities. The military, however, needs much greater flexibility, adaptability, and autonomy for Tier 2 if the warfighting requirements noted above are to be met. Thus the airborne platforms would carry intelligent radio nodes that perform all of the functions and services noted for the Tier 1 local-area network. Consequently, the airborne nodes provide automatic, adaptive, packet-data routing and switching. All airborne nodes automatically integrate themselves into an airborne network, and the unmanned aerial vehicle platforms automatically position themselves to provide survivable, fail-safe coverage of the ground-based units. Other airborne elements, such as mission aircraft, automatically provide relays of opportunity within the Tier 2 segment. A DoD program that is beginning to address this extended set of network services for Tier 2 is the DARPA Airborne Communication Node program.

As noted in Figure K-1, the airborne nodes are cross-linked not only to themselves and the ground local-area networks but also to the space segment of the transport element. The notion here is that the airborne nodes act as pseudolites and carry payloads that are integrated into the various commercial satellite telecommunication systems that have been and will be deployed in the next 10 years. As an example, preliminary analysis indicates that a Teledesic package (700 kg) could be accommodated on a DoD high-altitude, long-enduring platform. With an appropriate antenna, an active phased array, on a UAV, the resulting pseudolite could provide high-bandwidth communications services to and between ground elements and could route traffic automatically to the commercial space segment for long-haul services. Other approaches can also be envisioned: for example, the pseudolite could use commercial satellites as trunk facilities between the airborne relays. The critical technical issues in realizing this richly interconnected, survivable airborne transport segment are associated with the development of protocols and algorithms to provide the adaptive network services we have discussed.

Tiers 3 and 4

At the third tier, the information transport infrastructure provides connectivity over widely dispersed areas through incorporating low earth orbiting (LEO) satellites. The fourth tier includes medium earth orbiting (MEO) and geostationary earth orbiting (GEO) satellites for global coverage. The space-based transport segment should be based primarily on emerging commercial technologies. At the present time, many such systems with widely varying characteristics are expected to be available by 2005. Tables K-1 and K-2 summarize the systems that are currently being discussed. Table K-3 gives the maximum altitudes of LEO, MEO, and GEO satellites.

The challenge for DoD is to determine how best to leverage these emerging capabilities: more specifically, how to integrate these various systems with the other segments of the transport layer so that a ubiquitous, survivable, flexible, self-managed infrastructure results. Network- and internetwork-level algorithms are needed to integrate these disparate systems. These algorithms must be compatible with and exploit commercial internetwork standards and protocols. Specifically, they must be Internet Protocol (IP) aware. The entire transport layer must adhere to evolving Internet standards, such as IPV6 and Mobile IP, and must adhere to the well-established Internet naming and addressing conventions.

Table K-1. Voice-Oriented Personal Communications Satellite Systems[2]

System	IRIDIUM	GLOBALSTAR	ICO	ELLIPSO	ECCO
Company	Motorola	Loral Space and Communications/ QUALCOMM	ICO Global Communications	Mobile Communications Holdings	Constellation Communications
Number of Active Satellites	66	48	10	14	46
Orbit Planes	6 circular polar (86.5°)	8 circular inclined (52°)	2 circular inclined (45°)	2 elliptical inclined (116.6°); 1 elliptical equatorial (0°)	7 circular inclined (62°); 1 circular equatorial (0°)
Orbit Altitude (Km)	780 (LEO)	1,414 (LEO)	10,355 (MEO)	527-7,846 (MEO) 4,223-7,846 (MEO)	2,000 (LEO)
Satellites per Orbit Plane	11	6	5	4 per elliptical; 6 per equatorial	5 per inclined; 11 per equatorial
Beams per Satellite	48	16	164\3	61	32 per inclined; 24 per equatorial
Reported cost (Billions)	3.4	2.6	4.6	0.91	2.8

[2] Source for Tables K-1, K-2, and K-3: Evans, J.V. 1998. "New Satellites for Personal Communications," *Scientific American*, Vol. 278, No. 4, pp. 70–77 (April).

Table K-2. Data-Oriented Personal Communications Satellite Systems

System	ASTROLINK	CELESTRI	CYBERSTAR	SPACEWAY	GE*STAR	MORNING-STAR	TELEDESIC
Company	Lockheed Martin	Motorola	Loral Space and Communications	Hughes	GE Americom	Morningstar	Teledesic
Number of Active Satellites	9	63 LEO 9 GEO	3	20 MEO 16 GEO	9	4	288
Orbit Planes	Equatorial (0°)	7 inclined (48°); 1 equatorial (0°)	Equatorial (0°)	4 inclined (55°); 1 equatorial (0°)	Equatorial (0°)	Equatorial (0°)	12 inclined (98°)
Orbit Altitude (Km)	GEO	1,400 (LEO) and GEO	GEO	10,352 (MEO) and GEO	GEO	GEO	1,375 (LEO)
Estimated Satellite Capacity (gigabits/s)	6.0	1.5	9.0	4.4	4.7	0.5	10.0
Estimated Capital Investment (Billions)	4.0	12.9	1.6	6.4	4.0	0.82	9.0

Table K-3. Maximum Satellite Altitudes

LEO	Low earth orbit below 2,000 km
MEO	Medium earth orbit approximately 10,000 km
GEO	Geosynchronous earth orbit, 36,000 km

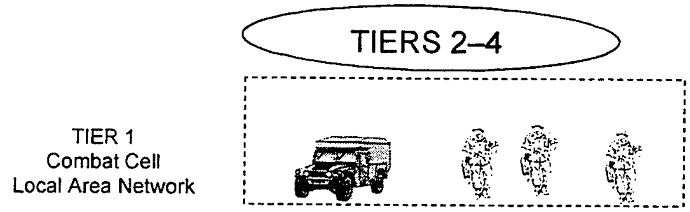
The routers, labeled "R" in Figure K-1, are commercial Internet devices that maintain, in real time, knowledge about the entire transport layer's topology and connectivity. [3] In conjunction with the intelligent software agents, the routers make dynamic decisions, based on this understanding, to ensure that information is transported from all sources to all destinations, as required. The dynamic routing is accomplished through protocols and distributed algorithms that are used in the commercial sector today.

WARFIGHTER'S PERSONAL INFORMATION ENSEMBLE

The warfighter connects to the broader information infrastructure through a personal information ensemble. This ensemble provides integrated multimode and multiband services, position and navigation, precise timing, and pertinent, tailored situation awareness through commands to, and reports from, the intelligent software agents. Warfighter interaction with the personal communications ensemble is interactive; it is voice and gesture based and hands-free; and it does not require computer or database expertise. Figure K-2 summarizes these attributes.

[3] Routers are currently used in the Internet.

Support for unit cohesion within small, distributed cells



- Integrated processing and communication resources
- A networked device that supports integrated multimode services: paging, conferencing, imaging
- Integrated postion and navigation function: precise time; terrain, enemy and teammate positions
- Support for QoS requests (e.g., bandwidth on demand)
- Support for multimodal interfaces (e.g., voice recognition, heads-up display)
- Integration into the III

Figure K-2. Warfighter's Personal Information Ensemble

The personal information ensemble is fully integrated with personal protective and other standard military equipment and offers antijam and security features. The protocols and algorithms developed for the warfighter's information ensemble will provide numerous services to the user. Examples of these services are multicast and broadcast information reception and distribution, conferencing facilities, network time (absolute and relative to a combat unit), and real-time reporting of a cell's geolocation and logistics status.

INFORMATION SERVICES LAYERS

The Integrated Information Infrastructure will provide tailored information to all users when and where needed. These services, provided by the intelligent software agents, include (among many):

1. Information fusion
2. Terrain information (topographical and feature) dissemination
3. Situational awareness (friendly and enemy) distribution
4. A common grid reference to permit joint, distributed targeting, and geolocation
5. Precision time
6. Information storage, retrieval, and tailoring

These agents – software entities that are autonomous, goal directed, migratory, and able to create other agents – will act on behalf of their owner. Achieving this level of intelligent behavior will be a technological challenge, but will be realized by the year 2020.

The private sector is developing information-service technology for the World Wide Web. Such services include Web browsers, search engines, and information-push systems. In each of these instances the conceptual framework of the service is modest: static profiling and filtering based on a-priori preferences established by the user. The software supporting these services does not yet learn users preferences, does not fuse data into information, does not adaptively manage information on behalf of a user, and is not adaptive to changes in transport services induced by failures, fluctuating user traffic, or intentionally induced performance degradation by a malicious adversary.

The private sector information management and dissemination services will, however, mature rapidly as a result of knowledge gained through DoD-funded programs such as GloMo, Battlefield Awareness Data Distribution, Agile Information Command Environment (AICE), and Intelligent Integration of Information. The end state envisioned is a system in which intelligent software agents, as described above, support the warfighter in the full spectrum of conflicts.

The military should exploit the information-management standards and technologies being developed by the private sector and must also continue to fund the science and technology (S&T) initiatives that will lead to the intelligent agents envisioned herein. DARPA and the Service laboratories have recently begun to focus their resources on developing core intelligent agent technology that leverages and supplements private-sector technologies and concepts in order to meet warfighter needs.

INFORMATION INFRASTRUCTURE: CURRENT DEVELOPMENTS

The vision and requirements for the Integrated Information Infrastructure have evolved during a period characterized by a remarkable rate of change in information technology. Within the past six years, commercial investment has propagated a World Wide Web of information services. Commercial activity is moving aggressively to set standards fostering open, interoperable systems. The commercial information technology industry investment in R&D is huge and growing as companies compete to rapidly transition information technology to the market place.

Within DoD, numerous studies on C^4ISR have been completed or are in progress. These studies recommend various strategies, visions, interoperability schemas, requirements, and architectures, but there is no overall, organizing principle against which these competing ideas may be measured. Further, DoD is sponsoring numerous and diverse technology development efforts, including multiple radio programs, C^4ISR platform and product initiatives, and programs to explore new technology in the areas of information collection, fusion and management. These, too, are poorly coordinated and duplicative, and are not organized along a central set of protocols and standards. To its credit, DoD is reorganizing to focus on C^4ISR, by appointing a Corporate Information Officer, among other steps. The success of this effort remains to be seen, since it resembles many such efforts in the past that had little real effect on the way DoD C^4ISR-related systems are planned and procured.

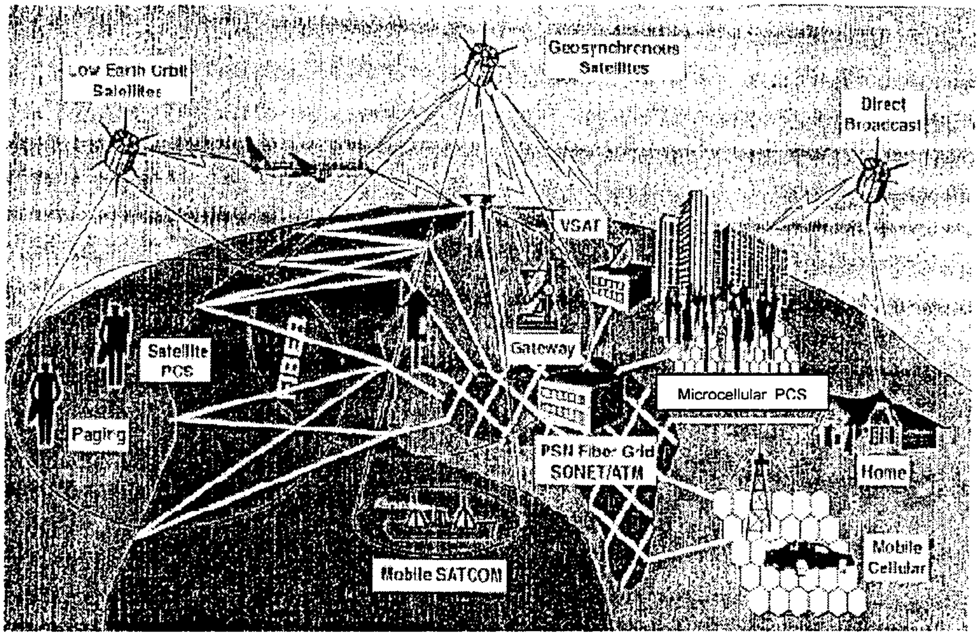
Similarly, DARPA and the Service laboratories are developing elements of the Integrated Information Infrastructure. Examples include, as described above, the GloMo program (investigating technologies to support mobile computing); the AICE (investigating broadband, broadcast information distribution); Intelligent Information Integration (investigating accessing and aggregating information for many heterogeneous databases); and network management technology development.

However, in all of these initiatives, the program goals have been pursued nearly independently of each other. Furthermore, the envisioned environment in which the various technologies are to be applied is modest compared to that envisioned for the III. In the latter case, we foresee many hundreds of thousands of communication and processing nodes distributed globally, all cooperating to provide robust, reliable information transport and intelligent information services to the combat cells and other users. The number of nodes involved and the fact that they are self-managed (on a peer-to-peer basis, in order to provide rapid adaptation to a continually changing environment) requires an S&T program focused on the intelligent information infrastructure envisioned for the III.

The Global Information Infrastructure today serves as an example of the ubiquitous connectivity that the distributed information infrastructure will require. The limitations of today's Web, especially at a "point of conflict" under stressed conditions, highlights the need for technology development to put an Integrated Information Infrastructure in place.

For example, America Online, Inc., experienced a 16-hour outage of its computer network on 7 August 1996. A similar outage in the distributed information infrastructure during a period of military operations (when that network is likely to be under the greatest stress) would be catastrophic. If military operations are to enjoy the benefits of leveraging information technology, we must ensure that the continued, uninterrupted functioning of that technology is accorded protection commensurate with its level of use.

Figure K-3, which shows the transport infrastructure that exists as part of the Web, is an example of what we envision for the III. Similarly, the information services (data storage and retrieval software) emerging on the Web are very early examples of what we envision for the intelligent software agents. This is not meant to suggest that the Web be the III, but that Internet technologies (protocols, standards, algorithms, and information application concepts) provide a starting point for establishing a baseline system in support of military operations. This baseline III, owned by DoD, would then be augmented through a DoD S&T program to realize the vision presented herein. Similarly, as commercial information technologies mature, they would also be integrated into the infrastructure. The technical challenges to be met by the S&T program are presented next.



The World Wide Web Today

Figure K-3. Transport Infrastructure: An Existence Proof

BUILDING THE INFORMATION INFRASTRUCTURE: TECHNICAL CHALLENGES

The following subsections discuss the technical requirements for specific elements of the Integrated Information Infrastructure and outline the technical challenges that must be addressed.

These technical requirements should be addressed by a well-focused DoD S&T program. The basis for the III will be commercial internetwork protocols, standards, and technology (albeit not those used in the Internet itself); commercial telecommunications technology (primarily space based, but also segments of the deployed optical fiber resources); and World Wide Web standards and protocols for information push and pull. This baseline would then be augmented to meet military requirements through continued advances in commercial information technology (IT) supplemented by the suggested DoD S&T programs defined below.

TRANSPORT RESOURCES

Requirements

The Integrated Information Infrastructure must provide fully integrated connectivity, ranging from strategic to operational to tactical to the combat units. Local communication resources must be internetted to area and global resources to ensure that the warfighter can, at all

times, communicate to entities intra- and inter-cell. These entities will include people, sensors, and weapons. There must be no seams between transport (communication) resources; all systems must be fully cross-linked and integrated into a network of networks – an internetwork.

All communication nodes (radios, switches, routers) must be intelligent. They must understand, in real time, their connectivity and, based on this knowledge, must provide dynamic, adaptive routing of information from sources to destinations. This adaptivity must be used to meet the quality of service (QoS), reliability, and survivability demands of the warfighter.

The transport infrastructure needs to be flexible and scalable. Flexibility implies that any network can be automatically integrated, via appropriate routers, with any other network(s), thus forming an internetwork. This flexibility is imperative in order to mix and match force elements (combined arms, joint, and coalition) to meet operational needs. Scalability of the transport segment of the infrastructure is required in order to support any number of distributed cells, weapons, and sensors to meet an operational requirement. Adding networks and/or communication nodes should be as easy as adding another network to the Web today (one is added every 30 minutes!).

Example Technology Challenges

To meet these requirements for an integrated, scalable transport infrastructure (that could include many hundreds of thousands of communication nodes), challenges such as the following must be met.

- The development of distributed algorithms and protocols that dynamically manage communication hardware to provide dynamic, real-time control of radio waveforms, link capacity and network topology; intra- and inter-network routing of data; distribution of network state information for adaptive, real-time self management; and distribution of state information exchanged between transport and information processing layers.
- The development of distributed internetwork management and control algorithms and protocols that permit the configuring of the topology and the balancing of loads across the network.
- The development of distributed algorithms and protocols that will adapt to meet dynamic QoS requests made by the warfighter.

Figure K-4 summarizes the III Transport Layer.

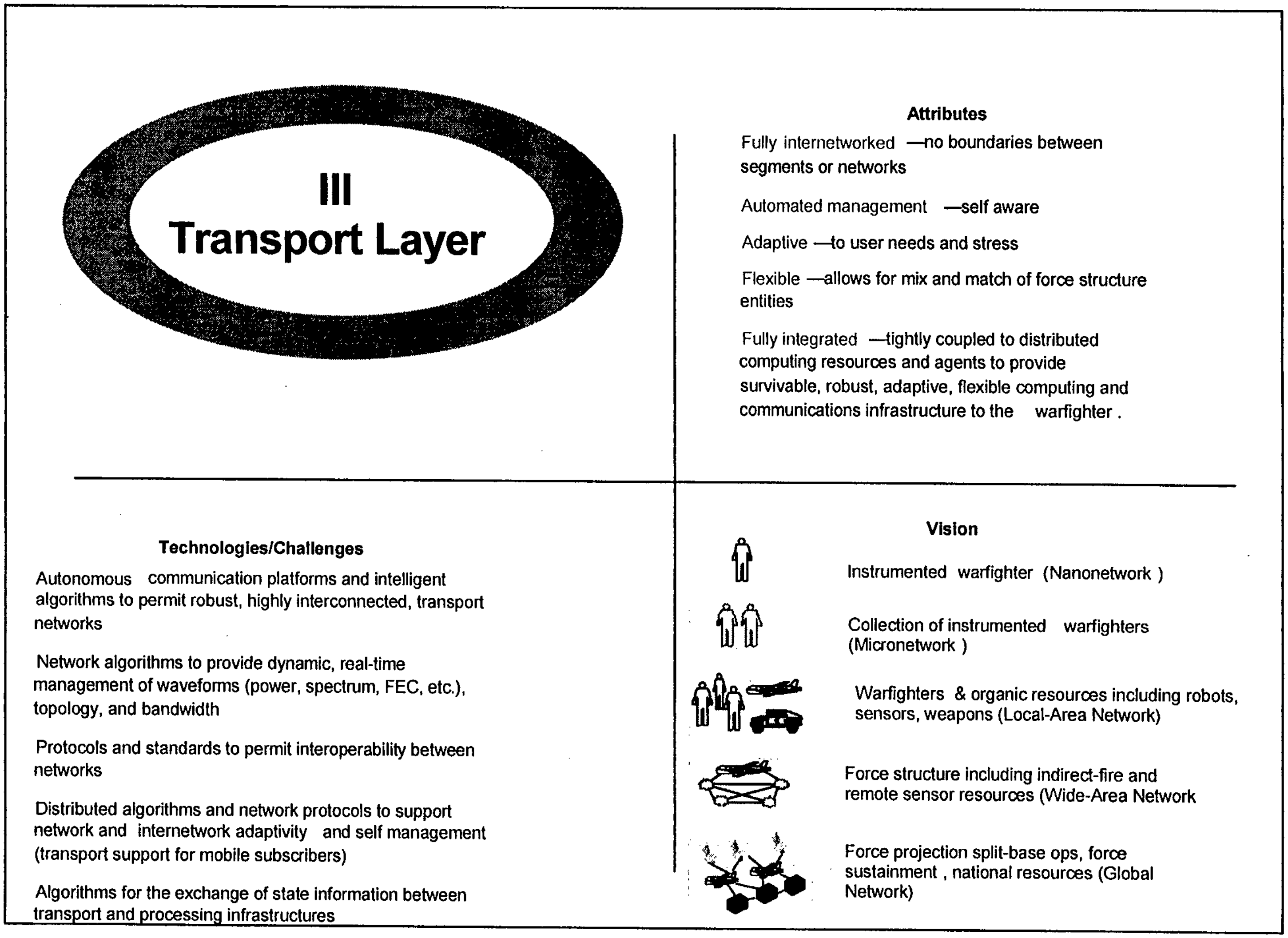


Figure K-4. Transport Layer

Distributed Computing Resources

Requirements

The information infrastructure must seamlessly, and transparently to the user, integrate distributed computing resources for user and software agent functions. Distributed processing must provide the necessary computational resources at all times and under all conditions, regardless of adversary-induced damage to the network. This is accomplished through dynamic resource management, wherein the network and network software agents intelligently respond to changing needs and network conditions.

Example Technology Challenges

- Operating systems that provide coarse-grained, distributed, parallel processing between dispersed processing systems;
- Distributed algorithms that permit dynamic load leveling, adaptive computation, and self management, to ensure graceful degradation at the point of service; and
- Algorithms and protocols that tightly integrate distributed computational resources with transport infrastructure.

Figure K-5 summarizes the distributed computational resources layer of the III.

Intelligent Software Agents

Requirements

Intelligent *service application software agents* must provide tailored, human-centric data acquisition, processing, and fusion, as well as information generation and dissemination to users. *These agents act to deliver processed, synoptic information to users instead of volumes of data and images.* The service application software agents collaborate with other agents to achieve general goals set by users, and, based on user profiling, proactively generate pertinent situation changes that may be of interest to the user. The agents support the automatic, dynamic, and adaptive allocation of transport and processing resources, and replicate themselves as necessary for efficiency and to ensure the continuity of services provided to the user.

Intelligent *application software agents* must provide an array of functions appropriate to the user's mission and situation, and must exchange information and status with other application software agents to provide integrated, yet distributed execution of requested user services. These agents automatically select and perform their functions according to specific user requirements and profiled user interest areas. The agents provide discovery and integration of data from multiple, heterogeneous databases, broker the sharing of information between other agents, and negotiate with service agents to establish appropriate network and resource allocation to achieve their goals. These agents are adaptive, in that they profile user needs against direct user input, past user requirements, and an understanding of user mission, status, and intentions.

III Computational Resources Layer

All resources integrated into a single, virtual megacomputer

Attributes

All processing resources integrated into a distributed collection of cooperative computers

Computation resources, in aggregate, provide nearly unlimited computational power

Resources available to all users of the infrastructure at all times under all conditions

Resources are automatically allocated/ deallocated to meet user's requirements and to cope with adversary

Technologies/Challenges

Heterogeneous processors ranging from massively parallel systems to high-performance, low-volume, low-power units

Ultrahigh-density data storage RAM

Disk-based operating systems to provide coarse-grained (distributed) parallel processing

Algorithms to permit dynamic load leveling, adaptive computation, self management, and reconfiguration

Algorithms to support dynamic resource management

Algorithms and protocols that tightly integrate computational resources with transport infrastructures

Vision

Processors to monitor personal status

Processors to support user access to infrastructures and to provide HCI* (voice recognition; high-resolution, heads-up displays; hearing augmentation, etc.)

Ultrahigh-performance personal digital assistants and desktop machines to support end-user

Ultrahigh performance processors to support embedded use (intelligent sensors, controllers, weapons)

Massively parallel machines to support computationally complex applications

*HCI: human-computer interface.

Figure K-5. Computational Resources Layer

Example Technology Challenges

- Protocols, standards and operating environments to support object-based system design and implementation, necessary to enable the creation of intelligent software agents;
- Representation technology for knowledge in object-based systems, by which software agents can describe their attributes to and understand the attributes of other software agents and resources;
- Representation technology for system resources, plans, and other entities in the infrastructure;
- Distributed algorithms, and appropriate protocols and languages, for agent definitions, communication, and adaptation;
- Universal representation of domain knowledge for exchange between software agents and resources;
- Comprehensive, universal language and computational models for declaring agents;
- Distributed algorithms and appropriate protocols for real-time distributed agent management, interagent negotiations, and information exchange; and
- Automated learning and user profiling techniques.

Figures K-6 and K-7 summarize the two layers associated with information services provided by intelligent software agents.

SECURITY

Security in the distributed information infrastructure merits special discussion. The exploitation of commercial protocols and standards provides the technology base necessary for the 21st Century integrated information infrastructure. Because portions of the infrastructure will incorporate commercial network technology, and much of the infrastructure will be based on commercial equipment, security must be an integral design consideration throughout the infrastructure's development. Further, because the infrastructure will also necessarily incorporate commercial systems, these systems must be carefully evaluated to balance the benefit of such incorporation versus the risk each such incorporation presents to the network. In general, commercial equipment offer little antijam or low-probability-of-intercept functionality, operate in generally fixed topologies offering limited adaptability, and require a fixed, predeployed infrastructure – leading to surge capacity limitations and potential denial of service problems.

Software Agents: Services

Agent: a software entity that is autonomous, is goal directed, is migratory, can create other entities, and provides a service or function on behalf of its owner

Technologies/Challenges

Protocols, standards. and environments to support object-based system design and implementation

Representation techniques for knowledge in object-based systems

Representation of system resources, plans, and other entities in infrastructures

Algorithms, protocols, and languages for agent definitions, communication, and adaptation

Attributes

Agents collaborate amongst themselves to achieve goals set by owners. Agents replicate as necessary for the efficiency and survivability of services rendered.

Agents automate human-centric, procedural functions: data acquisition and processing, data fusion, and information generation and dissemination.

Generic services provided include intelligent information dissemination to users, based on their real-time needs and situation.

Agents provide distributed, continuous, adaptive planning and scheduling services to warfighters. Agents support translation of heterogeneous plan representation and goal sets. Multiple planning approaches are supported through case-based, procedural, evidential and perceptual reasoning.

Agents support the automated, dynamic, adaptive allocation of transport and processing resources.

Agents provide automated database translation and fusion services.

Agents provide human sensory augmentation and support human-computer, multimodal interactions.

Agents support collaboration amongst themselves as well as collaboration amongst humans. Some agents manage the dynamic collaboration environment; others participate in the collaboration process as peers with humans.

Figure K-6. Software Agents: Services

Software Agents: Applications

Technologies/Challenges

Universal representation of domain knowledge

Comprehensive, universal language and computational models for declaring agent attributes, functions, domain knowledge, and methods

Automated techniques for the hierarchical decomposition of domain functions, processes, and information

Protocols and algorithms for real-time distributed agent management

Protocols and algorithms for interagent negotiations and information exchange

Automated learning techniques to enable agents to adapt to real-world situations

Attributes

Application agents automatically perform the user domain–specific functions currently accomplished by people.

Application agents are goal driven, and have a deep knowledge of their specific domains—process knowledge, information-requirements knowledge, and world-state knowledge.

Application agents broker between each other for sharing of information—they negotiate with service agents, as necessary, to achieve these goals.

Application agents automatically select and perform their functions at appropriate levels of granularity, depending on a specific user's requirements.

Application agents exchange information and status in order to provide integrated, yet distributed, execution of the domain functions they support.

Application agents adapt, via learning, to real-world situations. They perform intelligent data/information discovery and integration across multiple, heterogeneous databases.

Figure K-7. Software Agents: Applications

There are, however, market forces that will continue to aggressively force the private sector to provide security for the Global Information Infrastructure or the Web. Specifically, the growth of electronic commerce has already motivated the development of standards and technology for conducting secure information transactions. Examples of these standards and technologies are Internet Protocol Security; Secure Socket Layer; X.509; public key cryptography and key distribution mechanisms; strong encryption algorithms; intrusion detection systems; and inexpensive biometric systems (fingerprint readers and retinal scanners). These standards provide for information authentication, nonrepudiation, and secure transport.

However, the private sector has not yet addressed the issue of security for mobile code. Examples of mobile code are Java applets that are downloaded onto a user's machine and executed locally. Several approaches have been identified for securing such code including sandboxing, code signing, firewalling, and proof-carrying code; however, these approaches have yet to be implemented, tested, and standardized.

For the transport layer, we note that careful attention to information operations is mandatory. DoD must work with industry to ensure that the space-based segment of the III is made robust against information operations performed by an adversary. For example, protection of the control and signaling channels for the space nodes is critical.

Similarly, the Department will continue to be the focal point for developing low probability of intercept (LPI) and low probability detection (LPD) waveforms for the networked, primarily ground-based communication networks described previously. We note that software-programmable radios, such as JTRS radios, provide the flexibility needed to implement an adaptable, self-managed system. It should also be noted that this same flexibility provides an opportunity to enhance information assurance services. For example, the network-level protocols for these radios could make every node look the same (in a traffic analysis) as any other node, thereby limiting an adversary's ability to identify and target high-value, force-structure entities such as command and control centers. Similarly, the network-level protocols could, if the system detects it is being attacked, change its waveforms in such a manner that the radio emissions appear to be those of an adversary's unit, or change it to cause a radio node to appear to be a radar site. Network protocols and algorithms could achieve radio-network-based cover, concealment, and deception in ways never thought of in the past.

Requirements

Appropriate security for the distributed information infrastructure must be realized through the development of a comprehensive security architecture. Leveraging the security technology and techniques developed in the private sector, the architecture must provide flexible, dynamic, adaptive, and rapidly reconfigurable security in support of the software agents at work in the infrastructure.

Technology Challenges

- Distributed algorithms and appropriate protocols and representation technology to support dynamic security policy dissemination, arbitration, and enforcement within the distributed information infrastructure. These resources must include dynamic transport routing, data distribution, and processing and resource allocation.

- Techniques and technology that permit software agents to exchange security access credentials.
- Network-level protocols and algorithms that automatically exploit software-programmable radios' waveform flexibility to provide cover, concealment, and deception, resulting in information assurance.

INSTITUTIONALIZING THE INTEGRATED INFORMATION INFRASTRUCTURE

Realizing the III vision, and thereby achieving information superiority as proposed in Joint Vision 2010, will not be a simple undertaking. Broad issues will have to be surfaced and addressed, such as the use and integration of existing military C^4ISR infrastructures (both technical and capitalization issues); the definition of Service Title X responsibilities; the development of a C^4ISR acquisition policy; the definition of a single, unified DoD information infrastructure vision and champion, and the development of a single, integrated Joint Technical Architecture (JTA) supporting the III. However, it is our belief that all such issues can be successfully addressed if a unified Office of the Secretary of Defense, Joint Chiefs of Staff, and Service Chiefs' commitment is forged.

On the assumption that such a commitment is achieved, the III could be brought into being in an evolutionary manner over the next 20 years, with a milestone in 10 years for an integrated, flexible, efficient, joint C^4ISR infrastructure to support joint-force operations from strategic through tactical force levels. However, to achieve the mid- and long-term goals for the III, several critical DoD activities need to be started or reinforced immediately. These activities include the following.

First, establish a **single, unified OSD/Service vision**. Over the past years, several visions for an integrated, joint C^4ISR infrastructure have been proposed by JCS, the Services, and the Service Science Boards. These visions include the Network Centric Warfare (Joint Staff); InfoSphere (Air Force Scientific Advisory Board); Living Internet (Army); Integrated Information Infrastructure (Defense Science Board); IT-21 (Navy); and Advanced Battlespace Information System (JCS and Director of Defense, Research, and Engineering). Now is the time to develop a single DoD vision leveraged by the best ideas from each of these various visions and establish the integrated vision as *the goal* to be achieved by 2020.

Second, to achieve service C^4ISR interoperability and leverage the III with private-sector information technology, DoD and the services must embrace a **primarily commercial, standards-based joint technical architecture**. Very significant work within the Army and in OSD has resulted in the establishment of the JTA-Army (JTA-A) and a JTA. However, it is imperative that the JTA be a *minimum set of essential commercial information processing and transport standards and protocols*, augmented by DoD-unique standards only when absolutely necessary. A *minimum set* is critical to interoperability between Service and DoD C^4ISR infrastructures.

Third, **the JTA should be used as a basis for setting acquisition policy for all C^4ISR systems**. For example,

1. All new solicitations for C^4ISR systems should include compliance with the JTA as a technical evaluation criterion
2. All C^4ISR systems under procurement should include implemented transition plans for achieving compliance with the JTA when the systems are delivered
3. All legacy C^4ISR systems that are critical to the Services and that will remain in the inventory should also develop transition plans to be implemented through preplanned product improvement processes.

Although not all transition plans would be put into effect, (possibly due to cost or other factors), at least DoD can make an enterprise-level decision as to why the plans should not be implemented and what impact these decisions will have on joint C^4ISR interoperability. However, OSD, JCS, and Service goals should be to aggressively limit the number of non-JTA-compliant systems that remain in the DoD inventory after the transition period (about 5–8 years). The Army has implemented such policies, although waiver policies have become less stringent over time, and their experience might serve as a basis for defining and establishing DoD-wide policies.

Fourth, although commercial information technology will provide a wealth of systems, concepts, and resources necessary for implementing the III, there will remain a need to develop **DoD-unique capabilities that must augment the technology exploited from commercial sources**. Intelligent agent technology; adaptive, peer-to-peer, ground-based mobile communication networks; and LPD/LPI wireless waveforms are examples of a few areas that will require continued DoD S&T funding. Similarly, experimentation with commercial information technology will be mandatory, in a military context and integrated with legacy and military-unique C^4ISR technology, in order to evaluate the commercial technology and to understand its potential impact on military operations. Thus, a complementary DoD S&T program should be established that is consistent with a "revised" JTA (revised to constitute a minimum set of standards) and the associated new DoD acquisition policies. Specifically, the C^4ISR technology development supported through S&T funding (as well as advanced technology demonstrations and advanced concept technology demonstrations) should be compliant with the JTA to the maximum extent possible, or at a minimum must be compatible with the JTA, so that these technologies can be integrated into the III when completed. These new technologies will also provide input to periodic JTA updates when they result in commercial or DoD open standards that augment the JTA set.

Fifth, **a set of operational architectures** must be established that provides a framework for the types of joint forces deployed to the spectrum of operations envisioned in this DSB study. Although it is clear that we have "never fought the war we planned for," having an exemplar set of joint-force operational architectures that specifies which force elements must exchange information with which, as well as what they have to exchange, over what time frames, and how often will help set the requirements for the system architectures that realize the III. It is true that we cannot define the specific force structures we will deploy in the future: hence the flexibility required of the III to allow us to mix and match force elements; however, the set of operational architectures will help set boundary conditions for the system. The operational architectures should be developed with this objective in mind.

Sixth, **mid-term and a long-term system architectures** should be established. The mid-term architecture should identify all DoD C^4ISR systems that the mid-term III will comprise, as

well as the commercial protocols and standards used to integrate these systems, and the commercial technologies used to augment them. Examples of DoD systems and technology that the mid-term architecture might include are CTAPS, JSIMS, ATCCS, GCCS, GCSS, WIN-T, SINCGARS, JTRS, and commercial LEO satellites.[4] The architecture should, for each layer of the III, define the JTA-based protocols and standards used by each system, the interface specifications between the systems, a common application-level message system (such as the Joint Variable Message Format), standards for image and video representations that flow between the systems, and the like.

Similarly, for the 2020 time frame a conceptual system architecture that supports the ultimate III vision should be developed. This system architecture will set the direction for the evolution of the III system of systems.

Finally, a **series of joint warfighter experiments** should be planned that allow for the evolutionary deployment of the III. These time-phased experiments will serve to provide concept/technology/architecture course corrections as the III vision is realized. At the same time, these experiments will permit warfighters to adapt tactics, techniques, and procedures based on an integrated C^4ISR infrastructure that will provide joint information superiority.

Figures K-8 through K-12 summarize the above recommendations. These figures also assign responsibilities for these (and other related) recommendations and indicate an anticipated level of funding to achieve each recommendation.

One overarching recommendation should be added to the list: Implement the III. Developing the architectures is essential to the realization of the III, but an entity must be assigned the responsibility for ensuring that it is implemented. One suggestion is to broaden the charter of the Architecture Coordination Council from its present role of coordination to one of proactive management and oversight for implementing the III. Its mission will be to facilitate, motivate, and guide the realization of the III.

Getting it Done in the Next 20 Years

I. Implement the III

I.I Architecture Coordination Council (ACC) plays lead role for implementation

- ACC must
  - Accelerate the development of the three joint architectures
  - Ensure compatibility of Joint and Service architectures
  - Ensure JTA is promulgated within services
  - Develop III time-phased implementation plan
  - Oversee implementation of baseline III (2010) and full III (2020)

Who: USD A&T, ASD/C3I, J6
When: Immediately

Figure K-8. ACC Implementation Responsibility

4 CTAPS: Contingency Theater Automated Planning System; ATCCS: Army Tactical Command and Control System; GCCS: Global Command and Control System; WIN-T: Warfighter Information Network–Terrestrial; SINCGARS: Single Channel Ground/Air Radio System.

Getting it Done in the Next 20 Years

II. Establish Acquisition and Technical Architecture Framework

II.I Designate USD A&T (DAE) as the DoD technical architect with supporting executive director and staff

- Make executive director executive secretary of ACC

> Who: Secretary of Defense Direction
> When: Immediately
> Cost $10,000,000/year

II.II Technical Architect will

- Publish a unified technical vision for the III that incorporates the concepts from
  - Network Centric warfare (J6)
  - IT - 21 (Navy)
  - Infosphere (AF SAB)
  - Living Internet (Army)
  - Information Infrastructure (DSB)
- Revise the Joint Technical Architecture (JTA) as a *minimal essential* set of commercial IT standards and protocols to
  - Become the building code for the III and all C^4ISR systems
  - Limit military-unique standards
  - Establish policies for acquisition of all new C^4ISR systems to ensure compliance with JTA
  - Require JTA compliance transition plans for legacy C^4ISR systems
  - Make tradeoff decisions, as appropriate, for transition-plan implementation
  - Establish annual JTA update process

> Participants: ASD/C3I, Joint Staff and Military Services Chiefs
> When: First delivery December 1998
> Cost: $15,000,000/year

II.III Establish an IT advisory board to the executive director

- Composition: The best minds from the Service laboratories and academia
- Mission: Facilitate the realization of the III by
  - Monitoring and understanding commercial technology and military needs
  - Conducting risk/benefits analyses
  - Recommending DoD III technical investment to leverage commercial IT
  - Striving to minimize DoD-unique infrastructure
  - Provide Inputs to DoD system architect

> Implementation Responsibility: Executive director, with assistance from Service Laboratories
> When: Now
> Cost: $10,000,000/year

Figure K-9. Acquisition Policy, Vision, and Technical Framework

Getting it Done in the Next 20 Years

II. Establish Acquisition and Technical Architecture Framework (continued)

II.IV Develop an S&T investment strategy that allocates resources to meet military-unique aspects of the III

- Require technology to be compliant with JTA
- Require ATDs and other initiatives to integrate, develop, and demonstrate technologies compliant with JTA

Who: DDR&E with Service participation
When: September 1999
Cost: Within present funding resources

Figure K-10. DOD IT S&T Investment Strategy

Getting it Done in the Next 20 Years

III. Establish System Architecture and Development Strategy

III.I ASD/C3I, as DoD system architect, is responsible for:

- Developing and publishing joint system architecture
- Provide technical input to achieve III security and information assurance
- Assess C^4ISR transition plans and provide inputs to DoD investment strategies
- Track and provide technical guidance for all C4ISR and weapons platform acquisition, ACTDs and ATDs to ensure compliance with JTA and FIT into III System Architecture
- Provide technical inputs to JTA updates and configuration management

Who: Joint Staff and Service participation
When: Now
Cost: $30,000,000/year

Figure K-11. System Architecture

Getting it Done in the Next 20 Years

IV. Establish Operational Architecture and Deployment Strategy

IV.I JCS to develop and publish Warfighter Joint Operational Architecture that captures

- Operational concepts
- Processes and procedures for information generation, conditioning, fusing, and use
- Weapon, sensor, and platform functional characteristics
- Force structures

Who: With Service participation
When: June 1999
Cost: $25,000,000

IV.II ACOM to conduct a continuing series of experiments, with joint forces, to incrementally realize the III

- Exploit already scheduled joint and Service exercises
- Design and plan experiments
- Address and evaluate results
- Provide recommendations to joint operational architecture and joint system architecture
- Establish III Battle Laboratory as executive agent for experiment program

Who: JCS direction, ACOM execution
When: Start now
Cost: $40,000,000/year

Figure K-12. Operational Architecture and Experimentation

IMPLEMENTING THE III

As noted, the III must be implemented in an evolutionary manner. A plan must be established that sets specific functional objectives, technical milestones, and system architecture objectives that are to be achieved over reasonable periods of time. The plan will evolve as a result of lessons learned in the joint warfighter experiments suggested above, but nonetheless goals must be set. Examples of such goals, albeit too abstract for specific implementation, are discussed below.

Figures K-13 and K-14 provide a conceptual description of the III in about 2010. The cost of implementing this mid-term, baseline realization of the III would be in the range of $12-15B. These costs include funds already being expended or earmarked for C^4ISR system acquisitions and upgrades, the average yearly DoD investment in S&T for information technology, and the like. It is noted that these existing expenditures must be augmented to support the transition of the legacy C^4ISR systems to compliance with JTA and integration into the III.

BASELINE III - CIRCA 2010

"Lots of Legacy Augmented With Some Commercial"

- Users and sources know the location of repositories and store/retrieve information, using commercial push/pull technologies and services, e.g.,
  - Browsers (pull)
  - Channels (push)
  - Multicast, broadcast, and unicast.
- Military resources are augmented by commercial transport technologies, e.g.,
  - Commercial satellite telecommunications
  - Commercial satellite direct broadcast
  - Fiber (as available)
  - Secure end-to-end encryption of voice and data using public key encryption systems, technologies, and standards.
- Tiers 1, 2 and parts of Tier 3 deployed:
  - Tier 1: JTRS, PCS, and NTDR-like components
  - Tier 2: NTDR-like and JTRS components
  - Tier 3: PCS and Tier 2 trunking components.

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Figure K-13. Mid-Term III Vision

BASELINE III - CIRCA 2010 (Concluded)

"Lots of Legacy Augmented With Some Commercial"

- Fully integrated legacy C^4ISR systems are augmented with JTRS and some commercial information management and transport technologies:
  - C^4ISR information elements and types defined and implemented (e.g., messages, images, video)
  - C^4ISR information types implemented via open standards (e.g., MPEG2/4, WGS-84, object-based)
  - C^4ISR legacy transport systems seamlessly integrated via Internet standards and protocols (IPVG, Mobile IP, RSVP, QoS)
  - Messaging protocols and standards implemented to allow C^4ISR applications to interoperate (e.g., JVMS augmented for multimedia)
  - Service transport systems integrated within and across service boundaries (e.g., Living Internet (Army) integrated with Air Force and Navy internets)
  - Integrated information repositories defined and accessible to all sources and users (e.g., relational databases, image and video databases, Web pages).

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Figure K-14. Mid-Term III Vision

Of necessity, the mid-term III will include a significant amount of DoD C^4ISR systems augmented with commercial IT and services. The end game for the III, however, is that it be based primarily on commercial IT augmented by military-unique IT, if and when absolutely necessary and justified by cost/benefit/risk analysis. The evolution from the mid-term to the long-term III would occur over an additional 5–10 year period with $5-10B investment additional to that for the mid-term III. A high-level definition of the long-term III is given below in Figure K-15.

CIRCA 2020

"Diminished Legacy With Lots Of Commercial"

- Fully integrated infrastructure using primarily commercial information management technologies
  - Object-based representation of C^4ISR entities
  - Intelligent software agent supporting information push/pull
- Transport infrastructure including commercial LEO/MEO/GEO satellite communications systems:
  - Area, theater and global coverage
  - Cross-links between systems
  - Cross-links to airborne communications platforms
- Ground units supported by:
  - JTRS for mobile, adaptable, flexible, networked and internetwork
  - Commercial PCS for complementary services
- DoD ISR resources augmented with commercial and allied/coalition sensor satellites
  - SPOT
  - QUICKBIRDs
  - WIS

  Many others.

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Figure K-15. Long-Term III Vision

The ACC, with its augmented responsibilities for implementing the III, will be responsible for managing the III development. The ACC will have to harmonize the near-term, mid-term, and long-term operational system and the technical architectures that drive the III; develop the plan and road maps for the evolutionary deployment of the III; and ensure that DoD and Service funds committed to or planned for C^4ISR infrastructure acquisitions are focused on and supportive of achieving the III vision – a large but critically important task if information superiority is to be achieved.

SUMMARY

Figure K-16 summarizes the ideas and recommendations presented in this volume. The focus of this section has been on an III; however, the III must be implemented with reference to the ideas and recommendations presented in the other sections. For example, information operations will play a critical role in development of the III: they must be secure, provide information assurance, and be resistant to enemy attacks. Furthermore, weapons and sensors (as well as people) will use the III for information dissemination, exchange, cueing, fusion, and enemy engagement. As noted in Figures K-1 and K-5, the III will be common to and support all military platforms and their many diverse military functions. Thus, elements of the III will be embedded in all sensors, weapon platforms, and C^2 systems. Consequently, the JTA will apply to these entities as well. It is this view, *that all military entities and functions are part of and serviced by a common integrated information infrastructure that will permit us to exert, to the maximum extent possible, the power of our military forces in future contingency operations.*

- To realize the promise of Vision 2010, information superiority is a must
- To achieve information superiority, an integrated information infrastructure is a must
- An Integrated Information Infrastructure must
  - Be based on a unified DoD-wide III vision
  - Provide joint forces with common situational understanding, develop common operating pictures, and support informed and rapid decision-making
  - Integrate legacy C^4ISR systems and fully exploit commercial IT such as the Internet, personal computers, and satellite sensors
  - Be secure and provide information assurance, by:
    - Setting responsibilities and policies for developing and publishing joint operational, technical, and system architectures
    - Establishing policy and procedures to exploit commercial IT
    - Setting milestone targets for III deployment
    - Conducting evolutionary warfighter experiments leading to milestones/deployments/goals set for 2010 and 2020.

Figure K-16. III Summary

ANNEX L:

Mine Countermeasures

MINE COUNTERMEASURES

This Annex is extracted from, and amplifies, the US Navy/US Marine Corps Concept for mine countermeasures (MCM), the Naval Studies Board MCM recommendations, and other recommended actions in the MCM arena. This section also provides a framework for developing MCM capabilities in the littoral environment focusing on operations in 2010-2015. It describes the anticipated battlespace, identifies objectives for developing MCM capabilities, and describes required operational capabilities and technology enablers to support these objectives.

Forward presence and engagement are themes of Joint Vision 2010. A common thread among the Service's concepts supporting Joint Vision 2010 is a clear requirement to maneuver forces from the sea into the littorals. With the shift in focus by naval forces from the open ocean strategies to the littoral regions, the potential for mines to frustrate operational plans has greatly increased. American forces need an effective MCM capability to operate in distant waters in the early stages of regional hostilities, to protect vital follow-on sea lift containing supplies and equipment for the joint force, to allow swift littoral power projection operations, and to conduct follow-on clearance or humanitarian operations.

American forces have transitioned from legacy MCM operations which focused on port break in/out to operations involving expeditionary MCM in forward operating areas – "littoral MCM," as shown in Figure L-1. Rather than pursue an attrition approach through cumulative destruction, the commander must subject the enemy's mines and obstacles to rigorous surveillance and reconnaissance in order to locate and avoid them altogether or maneuver through existing gaps. When avoidance is not an option and adequate gaps are not readily identifiable, rapid, in-stride breaching of the enemy's mines and obstacles will be conducted. Organic MCM will provide forward-deployed forces the capability to accomplish mine detection, classification, identification, avoidance, and, when necessary, neutralization. Supporting MCM will be able to reinforce, as required, when the mission demands a capability beyond the capacity of organic systems.

FUTURE MCM ENVIRONMENT

In the future, the United States must be prepared to face a range of mine threats potentially far more lethal than those available today. More than 48 of the world's navies have mine-laying capabilities and access to mine inventories. At least 30 countries are actively engaged in developing and manufacturing sophisticated new mines. Of these, 20 are known mine exporters. An even greater number of nations possess the ability to lay land mines. Although most of the world's stockpiled mines are relatively old, they remain lethal and are easily upgraded. Often described as "poor man's artillery," mines present a significant threat on land, the beach, and in waters shallower than 300 feet. This is where the greatest number of mines are most effective and where power projection missions require that US forces operate.

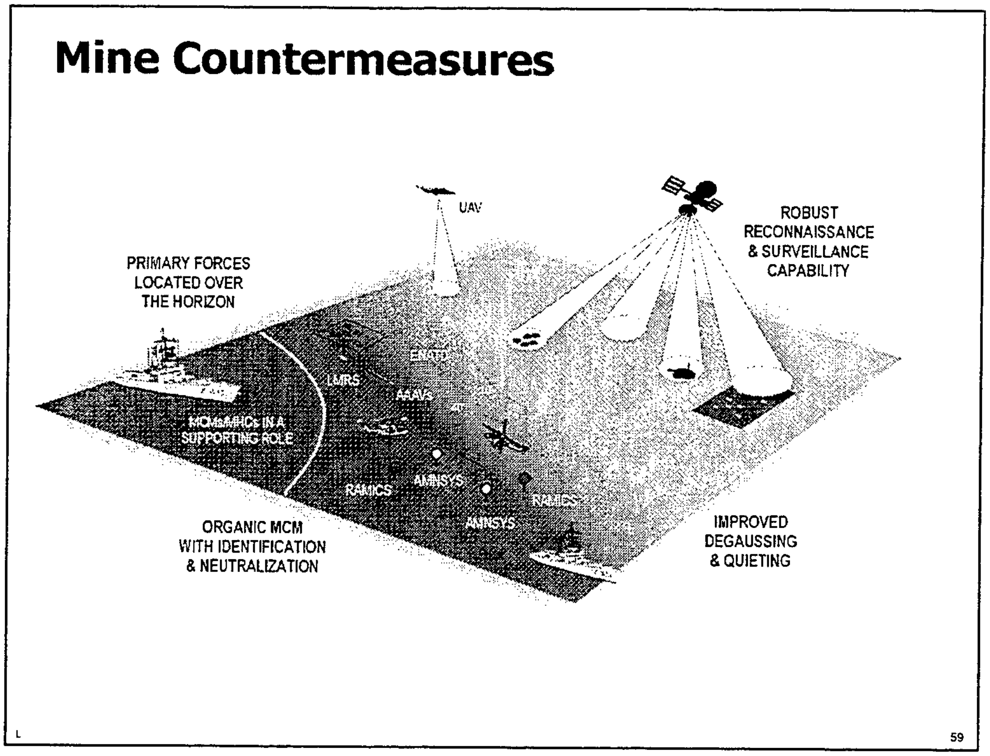


Figure L-1. Future Mine Countermeasure Concept

Five plausible mine threats include:

- Transiting the sea lines of communication/choke point,
- The seamless transition of operations from deep water to the objective inland,
- Carrier Battle Group/Amphibious Ready Group/Marine Expeditionary Unit Operating Area,
- Operations in support of port break-in, break-out and clearance, and
- Independent operations.

Threat nations may field advanced mines on their own, bypassing traditional development cycles by adapting market technologies to their needs. They will likely mine choke points, interrupt sea lines of communication, and use mines and/or obstacles in protective and defensive fields as counter-mobility weapons at anticipated landing or port break-in sites. Minefields will be laid on land, in deep to shallow water, and in conjunction with obstacles in very shallow water, in the surf zone, and over the beach. These defenses will be an integrated part of an adversary's overall anti-access plan.

The ability to strike with little prior notice will remain a critical requirement for exploiting the littoral battlespace. Littoral minefields demand significant attention and resources to avoid their restricting or disrupting the ability to maneuver at or from the sea. Although there will be some mines with improved capabilities, the greatest threat will be sheer numbers, rather than technological sophistication. That said, mines developed during the next 15-20 years will incorporate improvements, including:

- Cheap and widely available electronics and micro-processors allowing improved signal processing and logic capabilities, a reduction in firing mechanism volume, and power consumption;
- Application of modern signal processing techniques and the development of more sensitive influence sensors allowing larger threat radius and greater target discrimination;
- Increased explosive density providing greater lethality, especially in propelled warhead mines;
- Resistance to MCM using vehicle/ship counters, unconventional shapes, anechoic coating on mine cases, a reduction in metallic materials, active mine burial systems to reduce mine target strength, hardened mine casings, and blast resistant fuse designs; and
- Increased operating depths on land and sea, increased use of wireless or acoustic link remote control, longer ranges and improved guidance during attack for propelled-warhead mines.

The complex littoral environment, with its dramatic variability, exacerbates the problems and challenges associated with MCM battlespace knowledge. The diverse physical operating environment – above and below the water's surface and over the land – provides the foundation of MCM planning, preparation, and operations.

There are numerous geophysical parameters to consider when operating in the littorals; shortened scales of temporal and spatial variability are common to both the oceanic and atmospheric littoral regions. For example, major causes of variability in the littoral include ocean fronts, fresh water run-off, synoptic and local weather disturbances, sea and/or land ice and tidal fluctuations. These phenomena make it very difficult to accurately observe and forecast environmental parameters and, most importantly, to predict their effect on sensors, and thus military operations, especially MCM.

FUTURE OPERATIONS, CAPABILITIES, AND ENABLING TECHNOLOGIES

In a mine threat environment, MCM are key enabling activities. They must be given high priority and must be fully integrated into operational planning. Such planning will ensure the commander is able to maintain the flexibility that freedom of maneuver provides. Organic MCM, integral to the forward deployed force, will be capable of spanning the range of military operations. It must be equally effective at negating the impact of a mine threat on a dispersed force or forces operating in close proximity. Supporting forces will primarily be required for large area clearance when the battlespace permits, as well as for follow-on MCM operations.

Long-term MCM plans will include the development of coalition MCM forces. In all theaters where mines pose a threat, allied forces will be engaged to promote the establishment of multi-national MCM task forces. Theater Commanders must, in the future, include allied forces in combined MCM exercises in order to exchange tactics and philosophies, with the ultimate goal of building a fully interoperable and capable overall MCM force.

Command Considerations

Mines and obstacles have the potential to hinder a commander's ability to accomplish the mission. They will be used to slow or stop military operations and provide a means to control military and commercial traffic flow.

To accomplish the mission, the commander needs to know the role that mines and obstacles play in the enemy's overall offensive/defensive plan. The commander needs to be aware of avoidance techniques, the force's MCM capabilities, and self-protective measures. The commander also needs to judge whether the operational advantages accrued from crossing into a mine danger area outweigh those anticipated from inaction or avoiding the minefield altogether. To meet that challenge, the capability is needed to readily reconnoiter, collect, and disseminate intelligence, and mark or designate mine damage areas. This detailed knowledge must be gathered through early, sustained, and clandestine MCM reconnaissance. In certain cases, the commander may be given no alternative but to breach a minefield and perform limited clearing operations in support of the overall concept of operations. In some smaller scale contingencies, the objective may be to clear all mines.

Required Capabilities

Key to attaining a robust MCM capability is complimentary development of many technological capabilities. A viable MCM system encompasses technologies that detect, classify, and clear mines from the continental United States through the deep water, shallow water, surf zone, craft landing zones, and inland to the ultimate objectives.

There is no simple solution to enemy mining. Naval forces needs to develop and integrate innovative technologies, platforms, and sensors, and exploit the environment through a focused and streamlined infrastructure.

The future of MCM will depend on incremental and revolutionary technological development in the Department of Defense – specifically in the Department of the Navy. The Department needs to make a substantial investment in the research and procurement of MCM systems and provide the leadership to commit already heavily taxed forces to the MCM mission. This commitment needs to address the whole spectrum of technologies, infrastructure, connectivity, threat, and environmental knowledge with further consideration towards operational tasking, proficiency, maintenance, and sustainment.

As the focus of the MCM mission migrates from supporting MCM forces to a combination of organic and supporting forces, MCM education and training needs to evolve in two distinct and equal directions and in tempo with the development and deployment of innovative systems.

Mine countermeasures need to be viewed as an equal partner among the traditional warfare areas. It is a vital and critical enabler to carrier-based air power projection, sea-based air and missile defense, undersea warfare, and amphibious power projection envisioned in the early 21st century.

MCM Training

Future MCM systems will employ state of the art technology. Consequently extensive training will be required to operate and maintain these systems and understand the new technologies. MCM training in the future should:

- Ensure that units, both supporting and organic, carry out all MCM tasks against difficult training targets in real-world, less than favorable littoral environments;
- Emphasize multi-platform, cooperative MCM tactics, integrating land, air, surface, and subsurface MCM assets into appropriate fleet exercises;
- Stress the use of C^4I systems and computerized tactical decision aids;
- Exploit modern simulator technology to train individual crews;
- Link simulators and deployed naval platforms to practice coordinated operations in environments that match as closely as possible the situations forces will face during operations, ranging from crisis to high-intensity conflict; and
- Integrate MCM into battlegroup training for other littoral warfighting operations with portable, real-time linked minefield training ranges.

MCM Sensors and Platforms

Coordinated and Multi-platform MCM. Coordinated, multi-platform MCM operations optimize available sensors and systems, regardless of the host platform, to ensure that the most effective is used when and where it is most needed.

Fundamental to the MCM concept are early and accurate surveillance and reconnaissance techniques to rapidly and efficiently locate mines and minefields, and identify areas where mines are not present. This will require detecting mines or enemy mine laying activity anywhere in a large (thousands of square miles) area. If US or allied naval forces maneuver or operate in dispersed formations, the mine search area will increase several-fold. Effective surveillance and reconnaissance will rely on some form of cueing – normally from intelligence sources – to concentrate the search or, in the worse case, a datum established from a casualty.

Platforms. Rapid and wide-area detection, classification, and identification of mines, for avoidance, clearance, or breaching is critically dependent on platform characteristics. Future platforms require high performance capabilities in terms of speed, precision navigation, self-protective measures, range, endurance, communications and sensor payloads, mission turn-around time, and in the case of off-board systems, the 'footprint' within the host platform. An important consideration will be the autonomy of the system and the constraints it puts upon the host platform's ability to conduct other warfare missions. The mix and numbers of organic MCM platforms and sensors required to achieve mission accomplishment must undergo rigorous analysis, experimentation, modeling, and simulation.

Sensors. The harsh littoral environment markedly reduces the effectiveness of mine search and targeting sensors. This degradation is dramatic in the surf zone and riverine areas. Successful detection, classification, and identification of mines requires environmentally adaptive sensors, capable of overcoming poor signal-to-noise ratio at a significant stand-off distance. Future

sensors require high reliability and performance in processing speed, false alarm rate, sensor search rate (area coverage), positional accuracy, and in-situ environmental sensing.

MCM sensors need capability to conduct on-board (man out of loop) rapid mine detection, classification, and identification. As the need for high-speed maneuver increases, multi-spectral MCM sensor capabilities must be expanded for full integration with maneuvering forces. Sensors need to have sufficient fidelity to quickly and automatically discriminate clutter from real mines. It is essential that the system capabilities offer very high reliability and confidence factors. Furthermore, these sensors need to developed to provide rapid feedback to the operator of their performance and platform vulnerability.

Mine Clearance, Breaching, and Avoidance Systems. A commander needs the capability to confidently avoid mines or achieve the assured destruction or neutralization of a mine threat in the absolute minimum time. These systems must be effective against buried, ground, moored, or floating mines from the deep water to the anti-invasion mine on the beach and the anti-tank or anti-personnel mine on land. Furthermore, confidence that the job has been done requires the capability to relay accurate battle damage assessment.

An organic, in-stride mine and obstacle breaching capability is required for the landing force to facilitate rapid transition from deep water through the shallow water, surf zone, over the beach, and to inland objectives. The capability to expand the breach is also required to allow for sustainment and follow-on forces. Supporting forces and selective organic platforms will have the capability to deploy autonomous vehicles to neutralize mines using a variety or combination of methods such as influence sweeping or other techniques. In some instances, these vehicles may be used to conduct wide area 'influence jamming' to allow the safe passage of vulnerable units. The following emerging technologies offer potential in the MCM arena:

- Surface platforms that are remote controlled, unmanned, small, stable, long-endurance platforms, possibly based on SWATH technology;
- Unmanned underwater vehicles with a swim-ahead mine detection, classification, and neutralization capability;
- Precisely positioned (GPS-level accuracy), impact-buried bomb explosives timed to go off nearly simultaneously, forming an equivalent buried line charge to excavate a channel through the surf zone, craft landing zone, and through the minefield up the beach;
- A quick-setting polyurethane foam that when exposed to air forms a relatively tough rigid structure that floats on the surface. The foam should be capable of bearing the weight of heavy vehicles and the ability to absorb some degree of explosive blast energy;
- Stealthy surface and bottom-crawling devices to locate, classify, or neutralize mines;
- Airborne electro-optical reconnaissance systems such as “magic lantern”;
- Airborne lasers accompanied by a neutralization system capable of locating and destroying mines;
- Explosive nets and rocket-propelled line charges for neutralizing mines in the surf and craft landing zones—SABRE and DET offer this potential;

- Pulsed power through the use of intense acoustic or shock waves to disable mines at a safe standoff distance;
- Autonomous and semiautonomous networked undersea systems to enhance covert mine surveillance, detection, and neutralization capabilities;
- Biosensors such as human engineered mammal sonars;
- Holographic imaging utilizing electromagnetic mine detection technology;
- Mechanized semi-autonomous, tele-robotic complex obstacle and minefield breaching systems (Combat Breachings Vehicle P3I);
- Follow-on clearance assets;
- Off-route intelligent minefield neutralization systems; and
- Ground stand-off mine detection (GSTAMIDS) vehicle mounted.

Self-Protective Measures. Self-protective measures will not overcome the threat, but form part of the hierarchy of MCM tasks required to combat mines. While individual units need to be able to operate autonomously and have the ability to use organic sensors to detect, classify, and identify mines, the risk in a high mine threat environment of a 'leaker' is always possible. Selected platforms need the capability to maneuver through a mined area using detect and avoid sensors and possess a limited clearance capability to be able to free themselves when trapped within a mined area. All combatants could benefit from the capability to employ stealth – to manipulate unit signature and avoid triggering mine actuation. Signature control needs to improve to the point where mine actuation by a military unit rarely occurs. Sea-borne and some amphibious assault craft and land vehicles require the ability to withstand and resist the damage of a close proximity mine detonation. This may include methods such as improved construction, shock hardening for equipment and machinery, and protective materials.

SUGGESTED INVESTMENTS

Chapter 4 detailed the task force recommendations for mine countermeasures, which encourage the Department to develop an effective MCM capability. This section identifies some specific investments that will contribute to this goal.

- The US Navy has developed an organic mine countermeasures plan which will place a MCM capability directly in the carrier battle group. This capability is expected to begin in FY05 and reflect Navy's over guidance request in POM 00. If POM 00 stands as is, the implementation will slide by one year to FY06 and will take longer to complete.
- Organic MCM will consist of the following systems per carrier battle group: three Remote Minehunting Systems (RMS), three Airborne Laser Mine Detection Systems (ALMDS), three AQS-20X, three Airborne Mine Neutralization Systems (AMNS), three Shallow Water Influence Mine Sweep Systems (SWIMS), three Rapid Airborne Mine Clearance Systems (RAMICS) and one Long-Term Mine Reconnaissance System (LMRS).

- Incorporating organic MCM systems in amphibious ready groups and a review of associated additional lift requirements for the MCM capability within an ARG to include improved assault craft delivery of programmed MCM assets such as ENATD, SABRE and DET.
- Funding, accelerated development, and deployment of the beach zone area HYDRA-7 ICLS to clear beach areas for landing craft.

A brief description of each program and the funding required to implement the Navy's above core guidance request in POM 00 is provided below Although the DSB supports this organic mine countermeasure program plan and the POM funding profile, additional funding and emphasis is required in the very shallow water and beach landing zone/site mine countermeasure areas.

RMS: The is a remotely operated, surface ship launched and recovered, semi-submersible vehicle towing a mine reconnaissance sonar and is designed to detect bottom and moored mines.

$M	FY00	FY01	FY02	FY03
RDTE	34.9	42.1	25.0	15.0
OPN	0.0	0.0	49.1	67.0

ALMDS: The ALMDS is an airborne laser system that will operate from the H-60 helicopter and is designed to detect mines in the near surface zone.

$M	FY00	FY01	FY02	FY03
RDTE	20.2	18.7	15.5	22.6
OPN	0.0	0.0	0.0	0.0

AQS-20X: The AQS-20X is an airborne towed sonar that will operate from the H-60 helicopter and is designed to detect bottom and moored mines.

$M	FY00	FY01	FY02	FY03
RDTE	13.3	15.7	10.5	0.0
OPN	0.0	6.0	18.9	32.2

AMNS: The AMMS system is designed to clear bottom and moored mines from the H-60 helicopter.

$M	FY00	FY01	FY02	FY03
RDTE	5.5	3.2	4.0	1.9
OPN	0.0	0.0	0.0	6.7

SWIMS: The SWIMS is designed to sweep a shallow water mine field using magnetic influence. The improved SWIMS program will incorporate an acoustic influence capability. The system is designed to operate from the H-60 helicopter; however the system also needs to be adapted to a small surface platform to support the full range of very shallow water mine countermeasure missions.

$M	FY00	FY01	FY02	FY03
RDTE	4.9	7.8	12.6	14.7
OPN	0.0	0.0	0.0	3.6

RAMICS: The RAMICS advanced technology demonstration is evaluating the ability to destroy a mine using a super cavitating projectile fired from a helicopter. It is intended for use on the H-60 helicopter.

$M	FY00	FY01	FY02	FY03
RDTE	0.0	5.0	15.0	20.0
OPN	0.0	0.0	0.0	0.0

LMRS: The LMRS is an unmanned undersea vehicle designed to operate from a submarine and detect mine-like objects in an area of interest.

$M	FY00	FY01	FY02	FY03
RDTE	25.1	22.1	20.1	14.4
OPN	0.0	0.0	0.0	25.8

ANNEX M:

MPF-2010 Plus

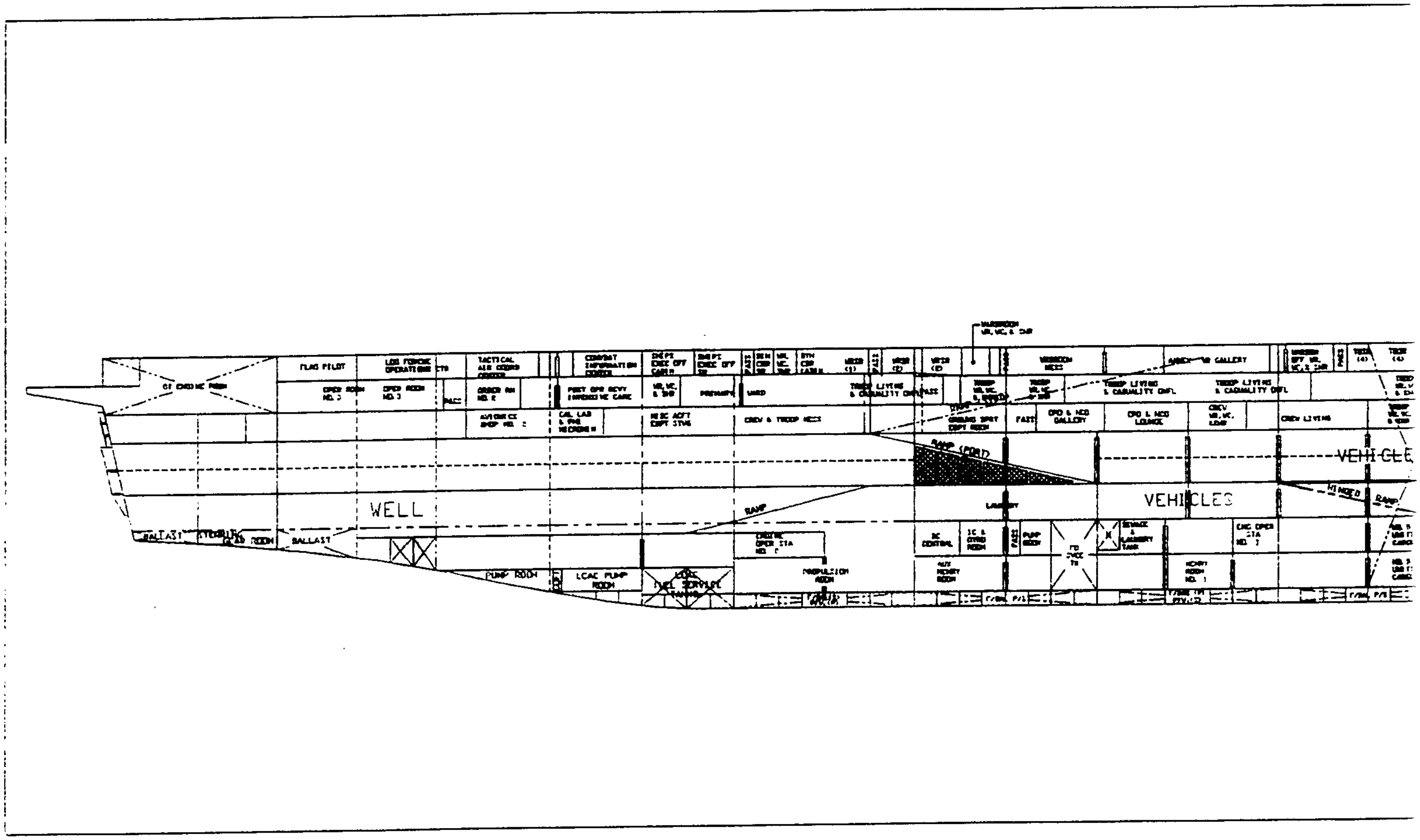
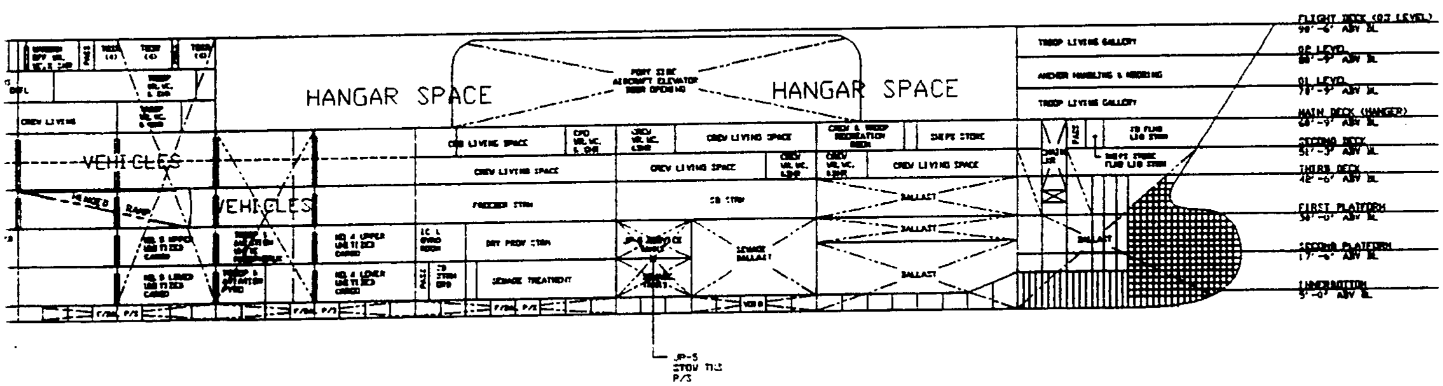


Figure M-1. MPF-2010



. MPF-2010 Plus

MPF-2010 PLUS

The United States has never been able to rely exclusively on forward basing or overseas access as a means of positioning forces to meet potential regional crises, and this is likely to be an even greater concern in the future. Reductions in defense resources demand concomitant reductions in the infrastructure costs associated with overseas bases. At the same time, an increasingly chaotic international political environment has dramatically increased the number of potential crisis spots in the world where the National Command Authorities might commit military forces. Under these circumstances, naval forces provide a robust capability for long-term, forward presence and power projection in littoral regions. In the future, as today, joint force commanders require a highly flexible capability to respond to the widely varied crises characteristic of the "new international order."

MARITIME PREPOSITIONING FORCES TODAY

Today's MPF rapidly deploys and assembles a robust force using a combination of strategic airlift and forward-deployed Maritime Prepositioning Ships (MPS) that include Army, Air Force, and Marine Corps prepositioned equipment. The essential requirement for an MPF operation is a secure area that allows for arrival and offload of ships and aircraft and the joining of personnel and material. Proof of the merit of the MPF concept was provided during Operation Desert Shield when MPF assets were deployed to Saudi Arabia within a matter of days. Later, in Operation Restore Hope in Somalia, MPS provided sustainment for US and combined forces as well as support for humanitarian assistance operations.

Today's MPF can conduct in-stream offloading and accommodate some combat loading. However, the future littoral battlespace will require a more robust capability. This more robust capability is needed to provide the joint force commander with enhanced flexibility and greater depth of sustainment across a broader range of missions. Thus, MPF need to evolve in order to fully support this battlespace. New technologies need to be pursued and existing technologies exploited to permit the next generation MPF to contribute to operational employment of military forces across the full range of operations, to include the rapid reinforcement of forward-deployed forces.

MPF-2010 PLUS CHARACTERISTICS

This *MPF-2010 Plus* is a fully aviation-capable ship with a 600-foot minimum flightdeck as shown in Figure M-1. This ship would be designed to handle aircraft from the SSTOL intra-theater airlifter to the Joint Strike Fighter, plus landing spots for rotary-wing aircraft. Moreover, all of the ships that comprise the MPF-2010 Plus force will have a well deck capability and be fully compatible with the current landing craft air-cushioned as well as the entire family of fast shuttle sea lift craft recommended in this study. This next-generation MPF will be central to the forward presence and power projection roles required to exploit the future littoral battlespace: capabilities which will remain central to US deterrence and conflict resolution strategies well into the future. The enhancements envisioned in *MPF-2010 Plus* will expand the functionality of the future MPF across an increased range of contingencies.

The *MPF-2010 Plus* ship design would take advantage of engine and computer technology – large aircraft derivative gas turbine propulsion engines and computer-controlled cargo handling and stowage systems – to both improve the mission capability and make it easier to construct. The propulsion plant arrangement would be an element of an electrical integrated power system. The propeller would be driven by a large electric motor located deep in the side hulls with the gas turbine generators located higher in the hulls. This plant arrangement eliminates one of the major design issues for amphibious ships – the long propulsion shafts needed to accommodate the well deck in the stern of the ship. With the gas turbine generators located higher in the hull, the penalty from large air intakes and exhaust ducts will be minimized.

Each *MPF-2010 Plus* ship will carry 10-15,000 tons of Army, Air Force, and Marine Corps materiel and over 2,000 troops. Together the air and ship delivery capability meets an offload rate of at least 400 tons per hour. Internally, the ship will be a sophisticated warehouse using modern material handling techniques driven by automated computer controls and computer based information system software to achieve the desired offload rate. To accommodate the mission requirement, a displacement of 55,000 to 65,000 long tons would be required.

Designs for computer-controlled cargo handling and storage systems would be based on current commercial cargo systems adapted for military use at sea. The *MPF-2010 Plus* class ship must possess the capability to conduct lift-on/lift-off and roll-on/roll-off operations with these craft in up to sea state three conditions, and they must be equipped with the requisite organic cranes and vehicle ramps to accommodate offload when conducting operations from a sea base. Key to the effectiveness of the ship is the ability to rapidly handle cargo and reconstitute supplies and equipment for direct use by forces ashore.

The ship must possess a robust command and control suite which allows for not only joint force ground and logistics command and control but also the aviation command and control required to operate organic and joint force aircraft. In order to optimize flight deck space for SSTOL operations, a below-deck mounted bridge or a telescoping bridge equipped with electro-optical sensor displays and a telescoping large (multi-purpose) radar, radio, and electronics mast are required features of the fully aviation-capable *MPF-2010 Plus* ship.

The ship possesses an organic intermediate level maintenance capability, including completely outfitted shops, service areas, material storage areas, and ready service spares storage and/or maintenance bays normally associated with an intermediate level maintenance capability. An aircraft hanger deck capability and elevators to move aircraft from the hanger deck to the flight deck is required.

In addition to other supplies and equipment, the *MPF-2010 Plus* needs to be capable of carrying bulk fuel and bulk water and possess the capability to make at least 100,000 gallons of potable water per day. The bulk liquids transfer capability must be compatable with aircraft, military, and civilian ships and the fast shuttle sea lift vessels.

The *MPF-2010 Plus* ships will require a medical capability commensurate with their expected operations and number of embarked forces. Viewed as a secondary casualty receiving and treatment facility, the new class of prepositioning ships would require operating rooms,

dental operating rooms, post-surgical suites, medical laboratories and storage facilities, and a medical convalescent suite.[1]

THE PILLARS OF MPF-2010 PLUS

The concept for *MPF-2010 Plus* is best illustrated through an examination of the pillars of future MPF operations: *force closure, amphibious task force integration, indefinite sustainment, and reconstitution and redeployment.*

MPF-2010 Plus **force closure** will provide for the at-sea arrival and assembly of the maritime prepositioning force via MV-22 or the SSTOL, eliminating the requirement for access to secure ports and airfields. Forces will deploy via a combination of surface mobility means and strategic, theater, and tactical airlift – including the MV-22 and SSTOL – to meet maritime prepositioning platforms while they are underway and enroute to objective areas. Units will be billeted while completing the process of making their equipment combat ready. The platform design must facilitate this preparation process by providing for easy access to all equipment for inspection, maintenance, testing, and selective reconfiguration of tactical loads. This enhanced force closure characteristic will permit elements of the MPF force to arrive in the objective area already prepared for operations.

Through **amphibious task force integration** *MPF-2010 Plus* will participate in operational maneuver by using selective offload capabilities to reinforce the assault echelon of an amphibious task force as shown in Figure M-2.

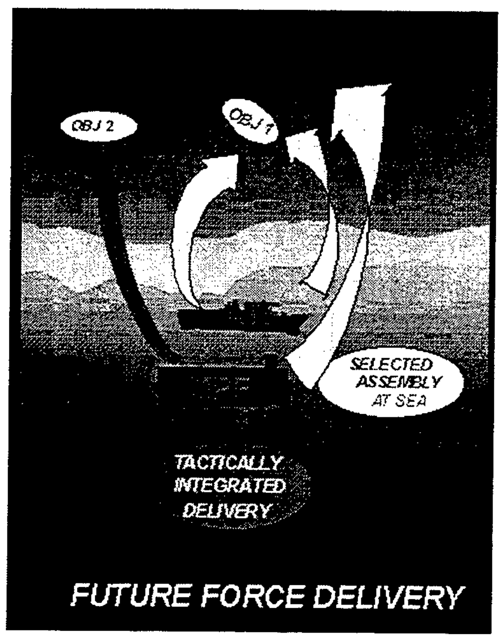


Figure M-2. Amphibious Task Force Integration

1 Center for Naval Analysis, John Nanee Jr. et al, Alexandria, VA, *MAA for MPF Future Sea-Basing Concepts, Volume I*, 29 June 1998.

MPF-2010 Plus will provide **indefinite sustainment** by serving as a sea-based conduit for logistics support. This support will flow from bases located in the US or overseas, via the sea base provided by *MPF-2010 Plus*, then on to units conducting operations ashore or at sea. This will be accomplished as part of a larger sea-based logistics effort which would include not only maritime prepositioning ships, but also fast shuttle sea lift, aviation logistics support ships, hospital ships, commercial ships, and offshore petroleum distribution systems. *MPF-2010 Plus* will also be able to integrate operations with joint in-theater logistics agencies and transition from a sea-based logistics support system to a shore-based system.

Upon mission accomplishment, *MPF-2010 Plus* will conduct in-theater **reconstitution and redeployment**, illustrated in Figure M-3, without a requirement for extensive materiel maintenance or replenishment at a strategic sustainment base. This ability to rapidly reconstitute the MPF force will allow immediate employment in follow-on missions.

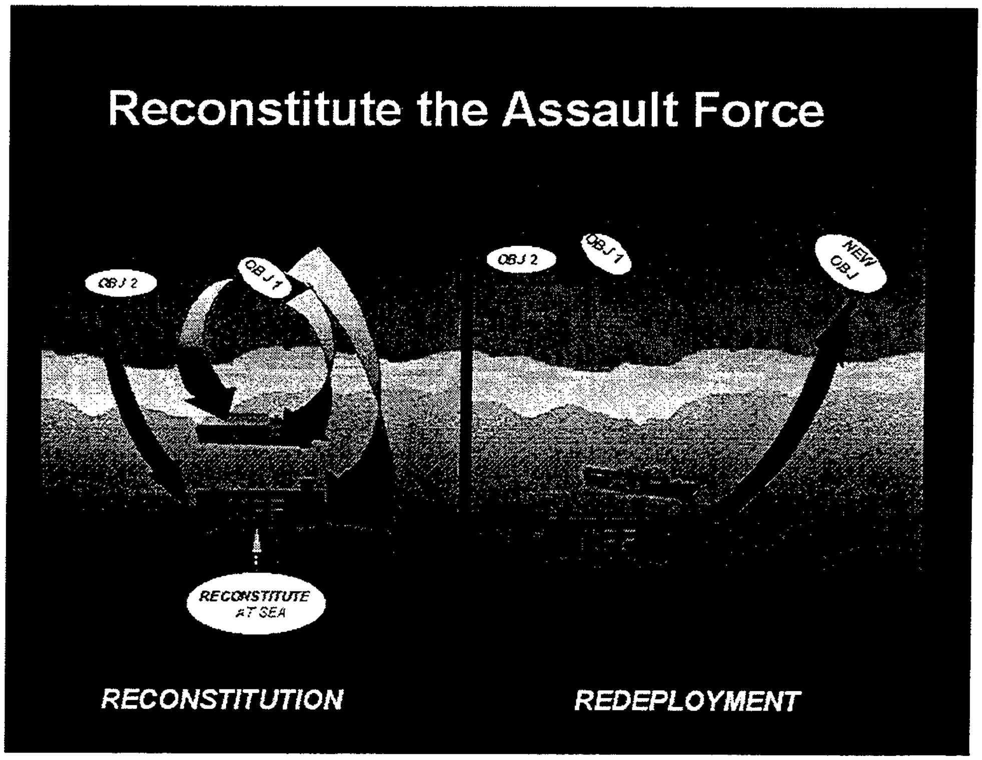


Figure M-3. Reconstitution and Redeployment

While the previously described pillars enable power projection by providing offensive capabilities, *MPF-2010 Plus* is more than a force employment concept. *MPF-2010 Plus* provides unparalleled **force protection**. Acknowledging the increasing threats presented by advanced anti-ship missiles and weapons of mass destruction, *MPF-2010 Plus* envisions conducting operations from over the horizon. Exploiting the sea as maneuver space, the dispersed, mobile MPF complicates the enemy's targeting process and takes advantage of the extended standoff range as combatants more effectively acquire and defeat incoming threats. A medium for movement for the MPF, the sea also serves as a barrier to terrorists or special operations forces

whose mission would be to strike at facilities established in the landing force rear. Whether major theater war or operations in support of smaller scale contingencies, the ability to reduce the landing force's footprint ashore by basing it at sea reduces exposure to threats from hostile forces, individuals, or the physical environment itself.

Beyond the physical protection afforded to what, in the past, would have been vulnerable rear areas ashore, the absence of those facilities eliminates the need for joint forces to defend them or their lines of communications from attack.

The centerpiece of *MPF-2010 Plus* will be a triad of new capabilities: *fast deployment*, *reinforcement*, and *sustained sea basing*. To perform the full range of MPF evolutions, all three of these capabilities will be required. In some contingencies, however, a joint task force may need only one or two legs of the MPF triad; *MPF-2010 Plus* will have the flexibility to constitute forces specifically tailored for each mission.

MPF-2010 PLUS: OPERATIONS

MPF-2010 Plus will integrate the pillars of the future MPF and triad of future MPF capabilities to enhance sea-based operations throughout the range of littoral power projection and forward presence functions.

MPF-2010 Plus has particular relevance in the context of military operations other than war. These operations typically involve limited numbers of joint forces in austere, but not necessarily hostile, environments. *MPF-2010 Plus* will offer the means to conduct such evolutions with a minimal footprint ashore. Initial operations might be performed by amphibious task forces, with MPF **reinforcement** capabilities providing follow-on forces. However, MPF-2010 Plus ships will also be capable of independent operations in such situations, using a combination of **fast deployment and reinforcement** capabilities. In many forms of military operations other than war, **sustained sea basing** will provide a critical advantage. Sea-based medical support and billeting may be especially important in environments where contagious diseases are a threat to friendly forces or when the host nation does not desire a large US presence. Additionally, the prepositioned stocks of supplies and equipment carried on board the ships could be made useful in a wide range of military operations other than war. Rations, medical supplies, tents, earth-moving equipment, communications equipment, vehicles, and water purification devices will be useful in many humanitarian assistance or disaster relief scenarios.

SUMMARY

MPF-2010 Plus is a major enabler in exploiting the littoral battlespace. It will establish a true US sea-basing capability, while enhancing force protection for forward deployed soldiers, sailors, and Marines. Free from dependence on shore-based facilities and overflight considerations, *MPF-2010 Plus* will offer unmatched operational flexibility to civilian and military leaders as they exploit the littoral battlespace and execute the National Security Strategy in the 21st century across the entire spectrum of conflict.

ANNEX N:

Fast Shuttle Sea Lift

FAST SHUTTLE SEA LIFT

Chapter 4 describes a concept for fast shuttle sea lift that will provide a vital link between a sea base and combat operation areas ashore. This Annex provides further detail on enabling technologies for this capability.

ENABLING TECHNOLOGIES

It is highly unlikely that most future conflicts will afford US forces the luxury of building up major forces in close proximity to the actual area of operations through the use of modern sea and air ports. Therefore, it is essential that US forces possess a forward-deployed capability coupled with the capability to offload significant amounts of equipment, supplies, and material from sea to shore, or deep inland. In addition to ship-to-shore mobility, joint force commanders require a capability to resupply the expeditionary sea base – an area consisting of both traditional military and civilian ships as well as strategic support ships espoused in the sea base/MPF-21 offshore expeditionary base concept portion of this report.

The fast shuttle sea lift ship concept provides a vital link between the sea base and both the combat operations area ashore and potential intra-theater arrival and assembly or distribution areas on friendly territory. Even with advanced aircraft such as the SSTOL concept discussed in this report, the amount of cargo that can be delivered by air will not fully satisfy the requirements of the joint force commander. The SSTOL will increase significantly the amount of support that can be provided by air; however, it is likely that the majority of required equipment, supplies and materiel will have to be delivered by sea. Moreover, the delivery of equipment and supplies will not be to modern seaports but to completely unprepared beaches and small piers. Although geography and weather effects may weight the air/sea equation on occasion, mass delivery of large supplies will always favor sea lift. Finally, the fast shuttle sea lift capability provides a viable means of resupplying the sea base from CONUS, intra-theater sources, or other support ships.

In order to provide the required ship-to-shore and intra-theater resupply, new intra-theater shipping must be researched and developed. Ideally, the new intra-theater vessels would be capable of lifting heavy cargo and vehicles over relatively short distances (1000-2000 nm) and at high speeds (50+ knots) in a sea-state three, or higher, environment. Several emerging technologies offer the potential to satisfy this requirement; however, a family of compatible intra-theater sea lift assets may best fulfill this requirement:

- SWATH/SLICE sea craft, as shown in Figures N-1 and N-2, for stability in heavy seas and high speed resupply of the sea base. A SWATH/SLICE vessel that has the capability to deploy quickly erectable causeways or conduct intra-theater resupply or offload of ships would provide the greatest benefits.
- Advanced surface effect craft for ship-to-shore movement over unimproved landing sites.

- Advanced air cushion landing craft – with potential folding "gull wing" technology to reduce embarkation space – as a replacement for the aging LCAC as shown in Figures N-3 and N-4.
- Quickly erectable causeways that can self deploy from other fast shuttle sea lift vessels – potentially the SWATH/SLICE vessel.
- High-speed advanced lighterage capable of offloading equipment and supplies from ships or the offshore expeditionary bases and then landing on varying beach gradients. This lighterage must also possess the capability to marry with expeditionary, quickly erectable causeways deployed from other fast shuttle sea lift craft.

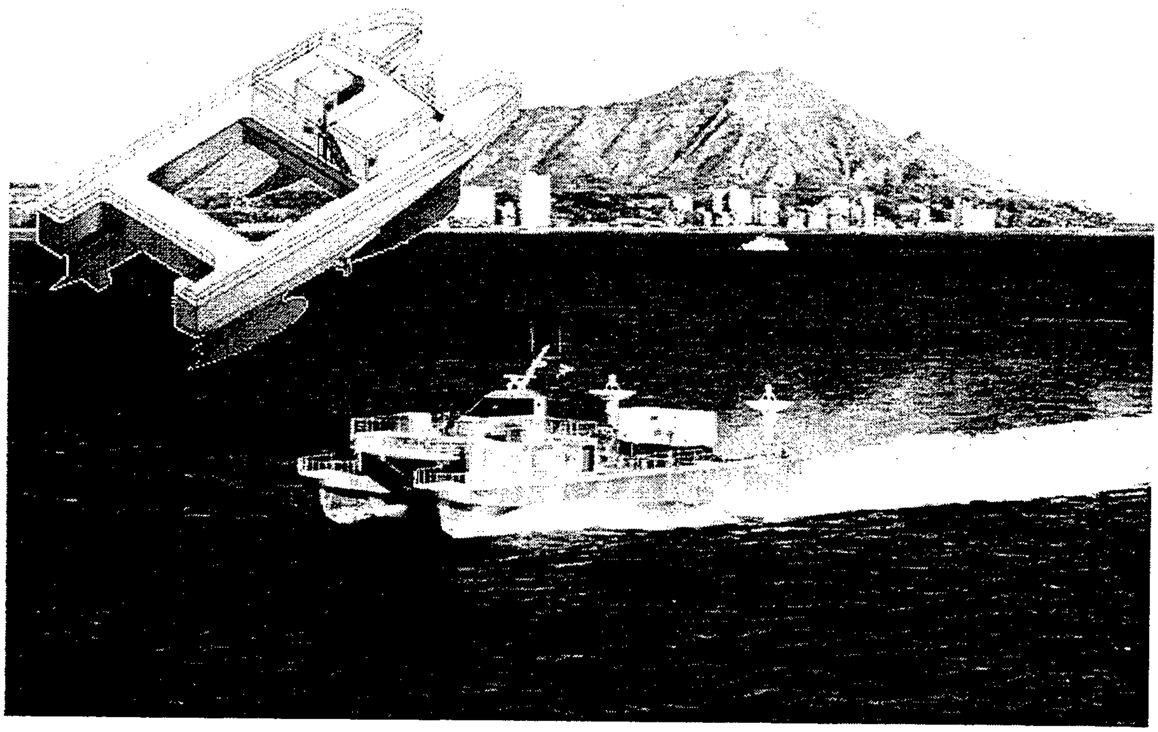
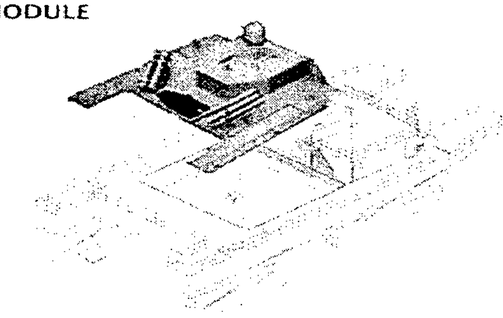


Figure N-1. SLICE Advanced Technology Demonstration

SWATH ships possess superior stability in high seas because most of their buoyancy is deep underwater with only narrow struts passing through the water surface. This reduces their sensitivity to wave action and allows open ocean operation but increases drag. A number of SWATHs are in Navy and commercial service, but are relatively slow because of this high drag.

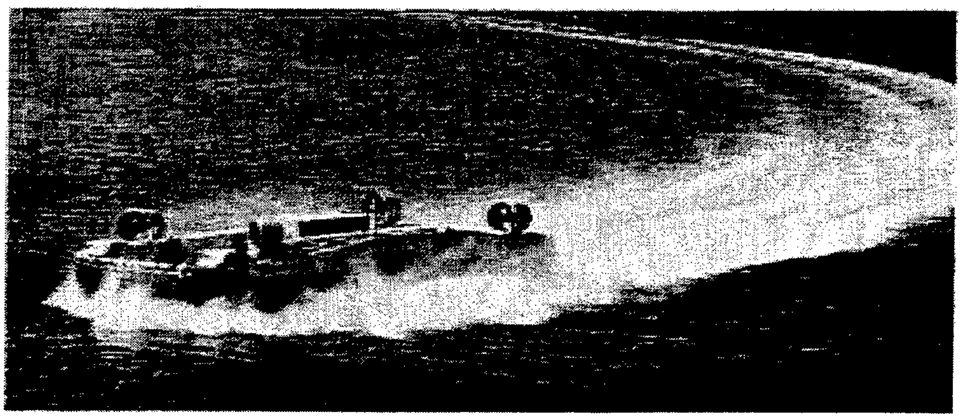
The SLICE advanced technology demonstration is designed to achieve both stability and low drag for high speed. The design speed is above 30 knots. Designed in a dual-use affordability environment, SLICE is of modular construction with a truly modular load carrying capability – either combat systems (radar, minesweeping) or commercial (fast ferry, high-value cargo).



General Ship Characteristics:

Displacement	180 Long Tons	Propulsion	(2) MTU 16V 396 TB94 6850 BHP
Speed	30+ kt	Propellers	(2) LIPS Controllable Pitch 7.2-Foot Diameter
Length Overall	104 Feet	Gears	Westech 3.5:1 Reduction
Beam (Max)	55 Feet	Generators	(2) Caterpillar 3306 DITA 360 KW
Draft (Full Load)	14 Feet		
Payload Weight (Max)	50 Long Tons		
Payload Length (Max)	57 Feet		
Payload Width (Max)	43 Feet		

Figure N-2. SLICE Characteristics



AALC JEFF (A) amphibious assault craft undergoing contractor's trials prior to delivery to the US Navy

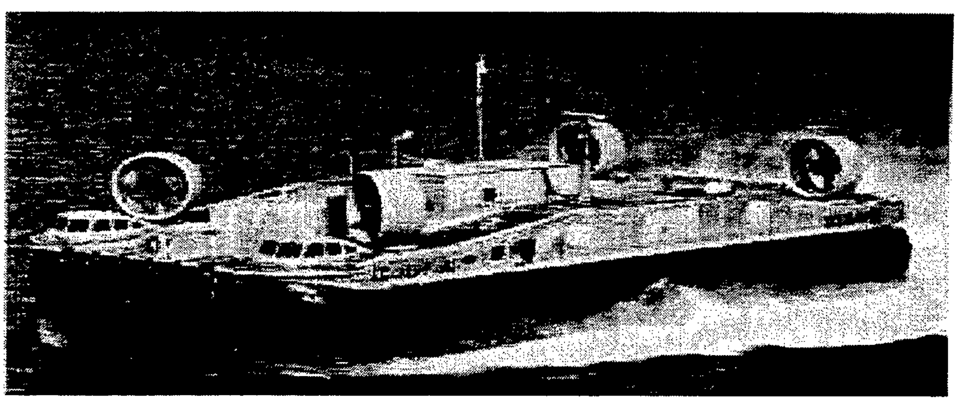


Figure N-3. Amphibious Assault Craft

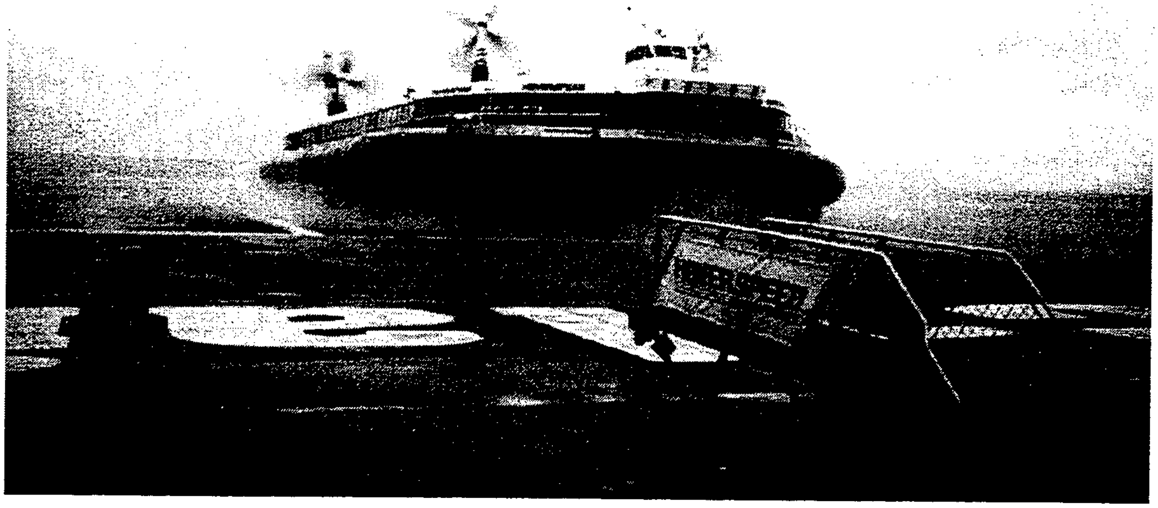


Figure N-4. Advanced Air Cushion Landing Craft Technology

The advantages to advanced air cushioned landing craft, as opposed to conventional landing craft or a fast shuttle sea lift ship without the capability to land across unimproved beaches, are many: they can carry heavy payloads, such as armored vehicles, at high speeds; their payload and speed mean more forces can be put ashore in a shorter amount of time, with less time between trips; finally, the air-cushion enables the vehicle to reach more than 70% of the world's coastline, as opposed to the 15% that conventional shuttle craft are capable of attacking.

In order to provide a balanced capability, all of the fast shuttle sea lift technologies must be fully compatible with each other as well as the offshore expeditionary base, commercial ships, and legacy military ships (such as amphibious ships and combat logistics force ships).

Deployment and employment options for the fast shuttle sea lift vessels will hinge upon the development of the offshore expeditionary base and its associated deployment/employment options. The favored option includes a robust fast shuttle sea lift capability that is resident on the offshore expeditionary base and augmented by other ships that possess a smaller capability. However, a rapid self-deployment from CONUS (without embarked supplies) capability should not be ruled out for the larger SWATH/SLICE intra-theater fast shuttle sea lift vessels. Likewise, an independent forward-presence capability – in addition to the assets on the offshore expeditionary base – may prove to be a worthwhile investment.

The existence of these new shuttle sea craft will enable sea-based operations independent of existing ports. Also, they will allow an increased logistic tempo while at the same time increasing the protection of material at sea prior to a shore delivery by keeping these "warehouses" of combat/logistic materiel at greater distance from shore. The basis for this stems from the development of high speed (50 knots), heavy payload (10 times the current LCAC unit

payload) small ships coupled with the ability to quickly erect causeways to mate with these small/fast special ships.

Force Characteristics Implications

This capability allows modest forward-deployed forces to influence strategic and political thought through presence and show of force. Moreover, by possessing the capability to rapidly project a viable combat force ashore and then sustain the force for an indefinite period of time, fast shuttle sea lift – coupled with the other tenets of exploiting the littoral battlespace in this report – provides deterrence and a potent, balanced warfighting capability. Finally, as part of a strategic joint force this capability has relevance across the spectrum of conflict – from humanitarian or peacekeeping missions to a major theater war.

ANNEX O:

Security of Office Buildings, Embassies, and Other Facilities Against Chemical or Biological Attack

SECURITY OF OFFICE BUILDINGS, EMBASSIES, AND OTHER FACILITIES AGAINST CHEMICAL OR BIOLOGICAL ATTACK

Embassies, military administrative buildings, housing facilities, and related political targets of terrorism are generally even less protected from chemical or biological attack than from attack using explosives. Existing technology, designing buildings to protect vulnerable points (for example, air and water supplies and food handling facilities), distributing personal protection systems, and training in response to threats or incidents would decrease the vulnerability of these buildings.

The successful attacks against US embassies in Nairobi and Dar Es Salaam in August 1998 emphasized the vulnerability of political targets abroad. These embassies were relatively unhardened against explosives and damage was extensive, but loss of life and injury to personnel was more extensive outside the buildings than inside. The United States and its allies are now relatively familiar with the threat posed by truck bombs and have strategies for mitigating this threat that will be more or less successful depending on the extent of hardening of the building and the magnitude and location of the explosion.

By contrast, there is little or no protection of US facilities against either a chemical or a biological attack, and the results could, in fact, be more serious for the inhabitants of the buildings than explosives. In rethinking the issue of security against explosives for embassies and other politically attractive targets, it is important to consider other threats as well. To harden facilities against explosives but leave them unprotected against chemical or biological attack is, ultimately, to encourage this type of attack.

THE PLAUSIBLE NATURE OF THE THREAT

We do not know how a chemical or biological attack on a facility would occur. But because it would likely be politically motivated terrorism, and plausibly intended to create casualties, it could be quite different than the type of attacks designed to hinder military operations. In particular, an attack on an embassy might most easily occur through food or water rather than by release of the agent into the air (respiratory attacks seem most probable against military facilities, although attack through water/food is also plausible for terrorist attacks against bases). A number of biological toxins – botulinum toxin, staph enterotoxin, ricin, abrin – would be easy to introduce into food and water, and because their onset of action is delayed, could expose a number of people before illness became apparent. Salad bars, dessert trays, water coolers, and other displays of foods that are open and kept at room temperature or below are especially vulnerable to contamination with biological agents. Since many of the biological toxins do not deactivate completely during cooking, cooked foods, coffee, and other drinks are also targets. These targets are also attractive for pathogens. (Salmonella 0157 H7 is an example of a serious pathogen that would be easily administrated through the food supply; cholera, Q fever, and anthrax are others.)

Attack through the HVAC system is also very plausible, especially in hot or cold climates when buildings are set up to operate predominantly with a single mode of internal climate control. Introduction of a volatile chemical agent (Sarin, mustard, phosgene, hydrogen cyandie) or a biological agent (as an aerosol or a respirable dust) could be very effective provided that the design of the system were known or it were possible to avoid filters (and probably very effective even with normal filters in place, since the filters ordinarily used are designed to take out dust and odors, not chemical or biological agents). The nerve agents have rapid onset, and warning would be immediate. Mustard, phosgene and phosgene oxime, biological toxins, and pathogens have delayed onset, and there would not be any obvious indication that an attack was underway.

Certain agents required for attacks on a terrorist scale are easily obtained. Ricin and abrin are available (from castor beans) in the quantities needed for biological attack and no more difficult to prepare technically than a simple explosive. Mustard, hydrogen cyanide, and phosgene are common chemicals, and making the few kilograms needed for an attack is a technical problem well within the competence of any organization having a college-level chemist and simple equipment. More sophisticated biological agents – botulinum toxin, anthrax, salmonella, Q fever and others – require a higher level of sophistication, but are still easily obtained. Websites and publications provide detailed procedures for making quantities of chemical and biological agents appropriate for terrorist attack.

The important conclusion is that even relatively unsophisticated terrorists could mount an effective chemical or biological attack with only a low level of technical sophistication. The probability that this type of attack will happen is increasing, as understanding of these agents increases, as defenses against explosive attacks becomes more effective, and as the risks and characteristics of chemical or biological attack are publicized heavily by the media.

PRINCIPAL ENABLERS

Many of the technologies that are being developed to protect other military assets against attack can be applied relatively easily and effectively to the protection of buildings.

- ***Air Supply***. Ultra violet (UV) and infrared biological monitors and "sniffers" of various sophistication (CAM, mini-mass spectrometers) can be used to monitor the quality of the air supply. Continuous UV irradiation of the building air supply would be technically feasible and effective to a large extent against air borne pathogens. Filter systems (HEPA and activated charcoal) can remove all classes of toxins, but is complex and expensive for continuous operation. Automated controls to rapidly shut down HVAC systems in response to indications from sensors indicating chemical or biological agents is entirely feasible and capable to limiting damage.

  For biological attack and for most chemical attacks, a simple hood with an air filter (Quickmask) would enable occupants to leave a building with high probability of escaping exposure. Gas masks are also effective, but more expensive and harder to use, and unnecessary for this problem.

- ***Water and Beverage Supply***. It would be straightforward to build internal water-supply systems that would be very difficult to breach. Locally supplied water and beverages – such as local bottled water, coffee services, and flavored drinks – are a vulnerable point.

- ***Food Supply***. The practicality of testing all food coming into a building will vary with the size of the building, and the local eating habits of the embassy. Thorough food testing, combined with warning, would provide some deterrence, and spot testing, combined with warning, would provide substantial protection. Protecting food and water supplies is probably best done by random testing during periods of low threat (as a deterrent) and buying from qualified suppliers with more intensive testing in periods of high threat. Many toxins and threat agents can be detected with assay technologies that are now available or being developed. Sterilization systems (high temperatures, ionizing radiation) or stores of prequalified packaged foods could provide alternatives to local supplies in times of high threat.

- ***Building Design and Operations***. Building security can be designed to explicitly protect against chemical or biological threats. Protection of the HVAC and water systems, the food supply, and other plausible portals (the mail room, shipping and receiving, reception) is easily possible, although difficult to enforce and maintain at a high level in routine operation. The technology used by the Navy to provide protected sanctuaries could be used to provide occupant protection if the threat grows or if attacks proceeding over long intervals seem plausible. In new buildings, designing in protected water and air supplies, and thinking through food handling, would substantially increase building security.

- ***Vaccination***. In high risk areas, vaccination would decrease the threat of certain agents. The risk of legal liability in vaccinating civilian employees of facilities depends greatly on the country.

- ***Medical Supplies***. Having the supplies needed to deal with attacks available locally (for example, atropine and pyridostigmine hydrobromide for dealing with nerve agents; antibiotics for biological exposure) and personnel trained to use them correctly would dramatically decrease casualties following a successful attack.

- ***Training***. Training occupants to respond to different types of chemical or biological attack, and exercising the security systems, is a key part of the success of any program designed to protect embassies or other facilities. A modest investment in training (and more broadly, in education in the nature of the threat and in signs to watch for) would probably have as great an influence on security as any technology.

A range of technologies are now available that would, if coupled with intelligence, warning, and appropriate training, substantially decrease the probability of an attack. Protecting that part of the food supply provided locally against contamination by biological agents is probably the most difficult problem technically.

MAJOR UNCERTAINTIES

The Threat. The most important uncertainty is anticipating the nature and timing of attacks. Effective coupling of information from the intelligence community with action from those responsible for counter-terrorism and building security is a crucial first step. The vulnerability of current embassies and US buildings abroad varies enormously. Understanding these

vulnerabilities and characterizing the potential of changes in protocol and retrofitting technology to the building are also required.

Response. The effectiveness of a response will vary greatly with the type of attack, the warning, and the level of preparedness and training of those responsible. If appropriate medical supplies are available, the effects of some attacks (especially by bacteria or rickettsia) can be blunted, particularly when there is a lag time before illness develops.

Decontamination. Following an attack, the facility must be decontaminated before it can be returned to use. Current technology for decontamination is inefficient and very labor intensive. Sensors that can be used reliably to declare a building "safe" do not currently exist.

Critical Technologies

Systems Integration: Sensors, Warning Systems, Passive Protection, Therapeutics. Most of what is needed to provide a dramatically higher level of protection is already available or is being developed under other systems. Because a building is a well-defined structure, with controlled access/egress of air, water, food and people, it is intrinsically better defined than other problems in defense against chemical or biological attack. A major issue is the integration of these technologies into a system that is effective in building protection.

Decontamination. There is presently no effective technology for building decontamination or for declaring a building "safe" once it is decontaminated. A number of technologies for decontamination are being considered, and some of them are very plausible candidates for building decontamination (ozone, uv, ethylene oxide, foams, sprayable coatings, self-decontaminating surfaces). The problem of building decontamination should be considered as a stand-alone issue, rather than trying to find decontamination technologies that fit all situations. The technical problem of standards and sensors for successful decontamination is crucial. Current sensors have high sensitivity for genetic and protein signatures of pathogens. These sensors do not show whether there are infectious agents present, and almost any successful decontamination will leave fragments of destroyed organisms. Distinguishing this biological debris from a legitimate threat is a complex problem, requiring careful examination well in advance of any event.

Chemical/Biological Hardening. Many of the assets of a building are in the form of records and office equipment: paper, computer disks, computers, and files. None of these systems will withstand typical decon procedures. Developing new technologies – passive or stripable coatings, safe storage facilities, non-corrosive decontaminating gases, and self-decontaminating coatings – could help restore a facility to function rapidly after an attack.

Recommendations

Priority. The problem of protecting US government facilities from chemical and biological attack should be given higher priority.

Risk Assessment. There should be a realistic evaluation of the level of vulnerability of embassies and facilities in the face of plausible treats from chemical and biological terrorism.

Mitigation. Develop a plan for cost-effectively introducing existing technology to protect buildings against the most serious chemical or biological threats. Implementing such a plan, would enormously increase their security.

Training. A major component of protection is that the occupants be able to use the systems that are available to them. Since the time-line for biological attack (and even chemical attack) can be relatively slow, a practiced response can have a greater influence on the outcome of an event than it would in an explosive attack. An explosive event is over in seconds, and thereafter everything is response. A chemical attack can evolve over 30-60 minutes, and a biological attack may involve days.

ANNEX P:

Glossary

GLOSSARY

AAA/RP	Advanced Aerial Attack/Reconnaissance Platform
AAV	Autonomous Air Vehicle
ACC	Architecture Coordination Council
AICE	Agile Information Command Environment
ABL	Airborne Laser
ACTD	Advanced Concept Technology Demonstration
ADAAM	Air Directed Air-to-Air Missile
ADSAM	Air Directed Surface-to-Air Missile
ALMDS	Airborne Laser Mine Detection Systems
AMNS	Airborne Mine Neutralization Systems
APOD	Airports of Debarkation
ASTOVL	Advanced Short Take-Off/Vertical Landing
ATG	Amphibious Ready Group
ASD (C^3I)	Assistant Secretary of Defense for Command, Control, Communications, and Intelligence
ATACMS	Army Tactical Missile System
ATCCS	Army Tactical Command and Control System
ATR	Automatic Target Recognition
BAT	Brilliant Anti-Armor Submunition
BMC^3	Ballistic Missile Command, Control, and Communications
BMDO	Ballistic Missile Defense Organization
C^2	Command and Control
C^3	Command, Control, and Communications
C^4ISR	Command, Control, Communications, Computers and Intelligence, Surveillance, and Reconnaissance
C/A	Clear Acquisition
CAV	Common Aero Vehicle
CBIRF	Chemical-Biological Incidence Response Force
CEC	Cooperative Engagement Capability
CEP	Circular Error Probable
CID	Combat Identification
CINC	Commander-in-Chief
CJCS	Chairman, Joint Chiefs of Staff
CJTF	Combined Joint Task Force
CMA	C^4ISR Mission Assessment
CONUS	Continental United States
CSS	Combat Service Support
CTAPS	Contingency Theater Automated Planning System
CTF	Combined Task Force

DARPA	Defense Advanced Research Projects Agency
DGPS	Differential Global Positioning System
DoD	Department of Defense
DSB	Defense Science Board
DTED	Digital Terrain Elevation Data
EDGE	Exploitation of DGPS for Guidance Enhancement
EFOGM	Enhanced Fiber Optic Guided Missile
EHF	Extremely High Frequency
ELF	Extremely Low Frequency
ELV	Expendable Launch Vehicle
EMD	Engineering and Manufacturing Development
FAA	Federal Aviation Administration
FLIR	Forward-Looking Infrared
FOPEN	Foliage Penetration
FSSL	Fast Shuttle Sea Lift
FYDP	Future Years Defense Program
GAM	GPS-Aided Munition
GATS	GPS-Aided Targeting System
GBS	Ground-Based Sensor
GCCS	Global Command and Control System
GEO	Geosynchronous Earth Orbit
GEODSS	Ground Based-Electro-Optical Deep Space Surveillance
GloMo	Global Mobile
GMTI	Ground Moving Target Indication
GPS	Global Positioning System
HAE UAV	High Altitude Endurance Unmanned Aerial Vehicle
HIMARS	High Mobility Artillery Rocket System
HMMWV	High-Mobility Multipurpose Wheeled Vehicle
HRR	High Resolution Radar
ICBM	Intercontinental Ballistic Missile
III	Integrated Information Infrastructure
IMU	Inertial Measurement Unit
ISLMM	Improved Submarine Launched Mobile Mine
ISO	International Standards Organization
ISR	Intelligence, Surveillance, and Reconnaissance
IT	Information Technology
IW	Information Warfare

J/S	Jammer-to-Signal
JASSM	Joint Air-to-Surface Standoff Missile
JCS	Joint Chiefs of Staff
JCTN	Joint Composite Tracking Network
JDAM	Joint Direct Attack Munition
JIATF(CC)	Joint-Interagency Task Force (Coalition Capable)
JLENS	Joint Land Attack Cruise Missile Defense Elevated Netted Sensor System
JRDEEF	Joint Rapidly Deployable Early Entry Force
JSOW	Joint Standoff Weapon
JSTARS	Joint Surveillance and Target Attack Radar System
JTA	Joint Tactical Architecture
JTAMDO	Joint Theater Air and Missile Defense Office
JTIDS	Joint Tactical Information Distribution System
JTRS	Joint Tactical Radio System
LCAC	Landing Craft Air Cushion
LEO	Low Earth Orbit
LIR	Light Infantry Response
LMRS	Long-Term Mine Reconnaissance System
LMS	Light Mechanized Strike
LOCAAS	Low Cost Autonomous Attack System
LOSAT	Line-of-Sight Anti-Tank
LOTS	Logistics Over The Shore
MAGTF	Marine Air Ground Task Force
MAWTS	Marine Aviation Weapons and Tactics Squadron
MCM	Mine Countermeasures
MEADS	Medium Extended Air Defense System
MEF	Marine Expeditionary Forces
MEF (FWD)	Marine Expeditionary Forces Forward
MEM	Microelectromechanical
MEO	Medium Earth Orbit
MIRV	Multiple Independently Targetable Reentry Vehicle
MPF	Maritime Prepositioning Force
MSTAR	Moving and Stationary Target Acquisition and Recognition
MTE	Moving Target Exploitation
OSD	Office of the Secretary of Defense
PCL	Passive Coherent Location
PLGR	Portable Lightweight GPS Radar
PsyOps	Psychological Operations
QoS	Quality of Service

RAMICS	Rapid Airbourne Mine Clearance Systems
RMS	Remote Minehunting Systems
ROE	Rules of Engagement
RRLCS	Rapid Response Liaison and Combat Support
RSTA	Reconnaissance, Surveillance and Target Acquisition
S&T	Science and Technology
SA	Selective Availability
SAM	Surface-to-Air Missile
SAR	Synthetic Aperture Radar
SBIRS	Space-Based Infrared System
SEAD	Suppression of Enemy Air Defense
SHF	Super High Frequency
SIAP	Single Integrated Air Picture
SINCGARS	Single Channel Ground/Air Radio System
SLBM	Sea-Launched Ballistic Missile
SMV	Space Maneuver Vehicle
SOF	Special Operations Forces
SOI	Space Object Identification
SOV	Space Operations Vehicle
SPB	Small Precision Bomb
SPOD	Sea Ports of Debarkation
SSTO	Single-Stage-to-Orbit
SSTOL	Super Short Take Off and Landing
START	Strategic Arms Reduction Treaty
SWATH	Small Waterplane Area Twin Hull
SWIMS	Shallow Water Influence Mine Sweep Systems
TBMD	Theater Ballistic Missile Defense
TEL	Transporter Erector Launcher
THAAD	Theater High Altitude Air Defense
UAV	Unmanned Aerial Vehicle
UCAV	Uninhabited Combat Air Vehicle
UGS	Unattended Ground Sensors
UHF	Ultra-High Frequency
USACOM	US Atlantic Command
USD (A&T)	Under Secretary of Defense for Acquisition and Technology
UV	Ultra Violet
VHF	Very High Frequency
VLS	Vertical Launch System
VTOL	Vertical Takeoff and Landing
WCMD	Wind Corrected Munitions Dispenser
WIN-T	Warfighter Information Network – Terrestrial
WMD	Weapons of Mass Destruction